PROGRESSIVE FURNACE HEATING

By ALFRED G. KING

A PRACTICAL MANUAL OF DESIGNING, ESTIMATING AND INSTALLING MODERN SYSTEMS FOR HEATING AND VENTILATING BUILDINGS WITH WARM AIR

Supplemented by

A COMPLETE TREATISE ON THE CONSTRUCTION AND PATTERNS OF FURNACE FITTINGS

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CONSTRUCTION AND PATTERNS OF FURNACE FITTINGS

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CHAPTER XX.

INTRODUCTORY.

A large part of the following text is compiled from a series of articles written for SHEET METAL.

To this text new material has been added, and the original work has been edited, revised and extended to make the book a useful, practical and instructive treatise on the subject of furnace heating.

Few of those at present engaged in the installation of the warm air furnace realize the possibilities of warm air heating.

The trouble has been with the many furnace dealers who have failed to be honest with themselves. Instead of adopting and following the motto "onward and upward" and working to uplift and develop the science of warm air heating (for it is a science) their rule seemingly has been "downward and cheapward," if the use of such an expression is permissible. They have thus done much to discredit this method of heating with the house owner and even with physicians and heating and ventilating engineers, who, of course, regard it strictly from the standpoint of efficiency and economy. It has not been the furnace (as it should be constructed) or the method of furnace heating (as the work should be installed), but rather the cheap, claptrap methods of furnace building and installation which have in a measure served to bring discredit on the dealer and manufacturer alike.

It is one of the peculiar laws of progression that while it often takes years of constant labor, energy and attention to work out the salvation of a business or a principle, the reputation and standing thus attained may be throttled as it were, over night, or, putting this thought into a concrete form bearing on our present discussion, one good job of heating will sell two or three other jobs and one poor job will result in the loss of ten others.

The indications point to a much more general popularity for the warm air furnace and an encouraging view obtains for a general expansion of the industry, hence every precaution should be taken to safeguard its growth.

Cheap competition work, the feverish endeavor to beat out a competitor by lowering prices to ridiculous figures, the use of inferior furnaces and materials, the catering to so-called "operation work" where from ten to one hundred or more houses are fitted with heating apparatus and where the saving of from five to ten dollars per house is looked upon as being a good stroke of business—these are some of the causes of condemnation brought about by the contractor.

Cheap furnace construction, the use of inferior materials, the gross overrating of capacities and the sale of furnaces to dealers who are ignorant of the principles of heating have been the manufacturer's contribution to the unsatisfactory conditions which long existed in this field. In actual results attained, this practice of cheap work is demoralizing.

The inability to properly warm a room may be due to faulty construction, an improper location of stack or register, lack of capacity at the heart of the system—the furnace—or any one of a dozen other causes. The dissemination of gas and dust into the rooms, the excessive consumption of fuel, the dry, oppressive atmosphere present in the heated dwelling—these and other marks of failure or unhealthful conditions may be remedied by the application of common sense methods.

ALFRED G. KING.

January, 1914.

Progressive Furnace Heating

CHAPTER I

THE CHIMNEY FLUE

The preparation for the installation of a furnace heating system should begin with the foundation of the building to be heated if the best results are to be expected from the operation of the apparatus. The erection of a chimney flue of proper size placed in the proper location is one of the principal points of building construction, making, as it does, for efficiency and economy in so far as the heating apparatus is concerned. Chimneys defective in construction and those located in isolated or inaccessible parts cause a large share of the failures of furnaces to work properly. It therefore behooves the installer to look well to the character and position of the chimney.

The human body has been likened to a furnace, and it is indeed a heating apparatus of the most delicate and intricate kind.

The mouth and nose may be called the draft door and chimney of the human furnace, and should the nose become clogged and the throat filled with matter, the fire of the body is suffocated for want of oxygen, the furnace ceases to work and the body dies.

As the ability of the human furnace to breathe properly is necessary, just so is the ability of the hot air furnace to breathe properly a necessity, if the full measure of work and activity of either are to be maintained.

The question of the chimney for use with a furnace is so important that it is the first thing to be examined when planning to install a heating apparatus.

Character and Size of Flue.

It is a well established fact that the draft in a chimney flue is spiral—that, as the air in the flue is heated and expanded by the hot gases and products of combustion, it rises in the flue, ascending with a spiral motion and increasing in velocity according to the amount of air passed through the grate of the furnace. In other words, the greater the opening resulting from the setting of the draft door, the more active will be the combustion of the fuel, and, if the

chimney be of the proper height and area, the greater the velocity of the draft.

It is by reason of the fact that the draft is spiral that a round smooth flue is preferable to all other styles of chimney construction. Next in value is the square flue, or one as nearly square as conditions of construction will permit. Fig. 1 illustrates a round tile flue encased in brick, representing the best possible type of construction. Should we suppose the tile to be 12 inches inside diameter, the chimney would have an area of 113 square inches.

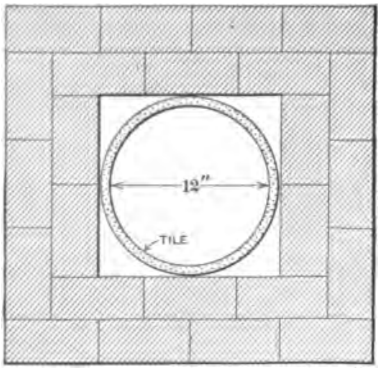


Fig. 1—Brick Chimney with Round Tile Flue.

Fig. 2 illustrates a square tile-lined flue, encased in brick. Assuming the width to be 12 inches, same as the diameter in Fig. 1, this flue would have an area of 144 square inches, or 31 square inches of area more than the round flue, and yet the latter will do the same work equally well, if not better.

Builders, and frequently owners, complain that a tile-lined specially built flue is costly. It is costly—not to build it. It is a continual fuel saver, and by saving from one to three tons of fuel yearly will soon pay for the increased cost. Very few investments will afford the same return in dividends as will the money expended for a good chimney flue.

The depth of a rectangular flue should never be less than the diameter of the smoke pipe which enters it.

Do not be deceived into thinking that a flue full large for the work means a corresponding increase in the consumption of fuel, as tests have demonstrated that a poor flue will frequently consume more fuel than one of proper size, and at the same time produce less results in heat units delivered to the rooms to be warmed. When fuel is burning under the former condition there seems to be no life to the combustion.

The fire is a dull red, the smoke pipe is cool, and the temperature of the gases in the flue is so low that proper conditions of draft are out of the question.

It is all important that the furnace dealer should post himself thoroughly on chimney construction. It is the first and most necessary study in qualifying as a heating expert. A furnace man has no business to install furnaces when he is not capable of advising as to proper chimney construction.

Beware of long narrow flues, because but a small portion of the area of such can be counted upon to prove effective.

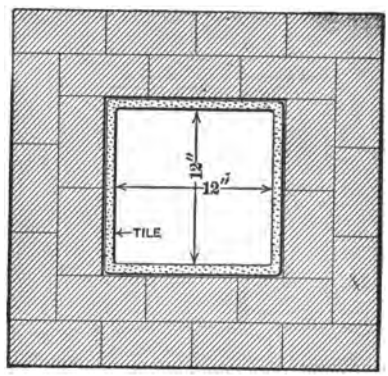


Fig. 2—Brick Chimney with Square Tile Flue.

For example, a flue 4 by 16 inches may be rightly considered as being no more effective than a 6 inch round pipe. The dead air area in the ends of this rectangular flue is of no value whatever. On the contrary, it is frequently a hindrance, owing to friction and down-draft likely to prevail. Fig. 3 illustrates this fact, the shaded portion of the flue representing its effective area. If a flue be built of brick without a tile lining, it should be pointed smooth on the inside, not plastered, as the plaster lining will loosen and drop down in patches, frequently taking a quantity from between the bricks, thereby loosening them and damaging the chimney.

By adding to the height of a chimney the velocity of the flue may be increased at small expense. The area, however, cannot be well increased without considerable cost, and it should therefore be great enough from the start to fulfill all possible requirements.

All chimneys should be built straight from bottom to top without offsets of any character. Where an abrupt

offset is made in a chimney a place is provided upon which soot will lodge and after a time clog the flue opening, as shown by Fig. 4. This is a common cause of the failure of many flues in city houses where a block is built up solid with openings or area-ways left for passage between houses, the second floor being set out over the area-way. Chimneys are often offsetted three or four feet in this style of building construction, and as a result prove a great detriment to the successful working of the furnace.

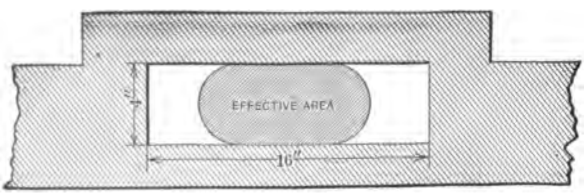


Fig. 3—Rectangular Flue Showing Effective Area.

A chimney to be effective at all times and under all conditions of wind and weather, should extend at least two feet above the highest part of the roof. The wind will travel over the roof of a house or that of an adjacent building and practically cut off the draft of a low chimney beneath. Fig. 5 illustrates this condition, the arrows indicating the direction of the wind and the dotted portion of the chimney showing the height to which it should have been erected.

Area and Height Required.

A chimney has two principal factors—area and height.

There must be sufficient area to pass the volume of air required to properly burn the fuel. Three hundred cubic feet of air is necessary to supply the oxygen required to consume each pound of coal.

For example, suppose we are operating a furnace having a 27 inch grate, the rate of combustion being 4 pounds of coal per square foot of grate per hour. A 27 inch grate has practically 4 sq. ft. of area, hence $4 \times 4 = 16$, the number of pounds of coal required per hour; and $16 \times 300 = 4{,}800$ cu. ft. of air per hour, the volume necessary to properly burn this amount of fuel.

One authority says: "Each atom of carbon requires for its perfect combustion two atoms of oxygen. When this

union is effected it burns to carbon dioxide and yields per pound 14,500 B.T.U. (heat units).

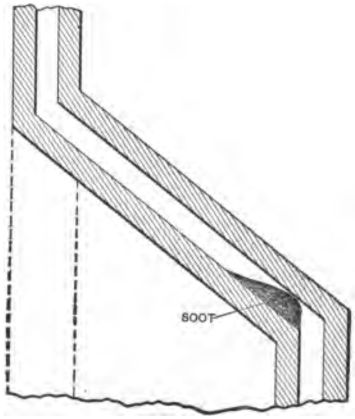


Fig. 4—Offset Flue Showing Accumulation of Soot.

"If, however, through insufficient air supply there is but one atom of oxygen to one of carbon, the result is carbon monoxide yielding 4,500 B.T.U., or less than one-third the heat given off where combustion is perfect."

Fig. 5—Effect of Wind on a Low Chimney.

We know the statement of this chemist to be true, because it has been demonstrated that when the flue is too small and too little air passes upward through the coal, the fire has nc life or activity, and the fuel is consumed without producing effective results.

The height of the flue should be sufficient to clear the roof of the building or any surrounding roofs or obstacles, so that the wind striking the roof will not cut off the draft by being deflected over the top of the chimney, as illustrated by Fig. 6, which gives another example of the action of the wind upon a low chimney.

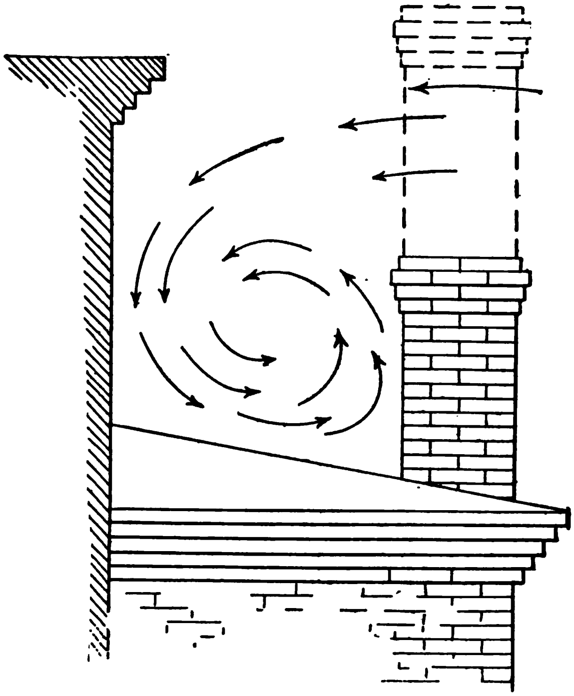


Fig. 6—Illustrating Action of the Wind Upon a Low Chimney.

The height (preferred) of the chimney for the average house is from 30 to 40 feet, and this height is sufficient for the velocity or sharpness of draft demanded.

Many owners of buildings have mistaken intensity of draft for volume, and many heating contractors test chimneys by setting fire to a newspaper and crowding the same into the chimney flue through the opening for the smoke pipe. If the charred paper goes up the flue with a roar they think the chimney is perfectly satisfactory. The fact is that a six inch pipe would show exactly the same results.

How Correct Tests Are Made.

Draft gauges of various kinds are used for testing purposes. Among heating engineers the strength of draft in a chimney is measured by the inches of water required to equalize it.

Fig. 7 illustrates a portable draft gauge with a funnel. A piece of glass testing tube is heated and bent to the form shown. The funnel is made of tin and is of sufficient size to cover the ordinary smoke pipe hole of the chimney. Some felt cloth or soft felt paper tacked or pasted around the smoke pipe opening will allow the funnel to seal the opening tightly and thus will show more accurate results. A gauge scaled in inches and tenths of an inch is adjusted into the upright end of the tube as shown. The tube is fastened to the small end of the funnel with plaster of Paris and is filled with water to a point one-half way up the scale.

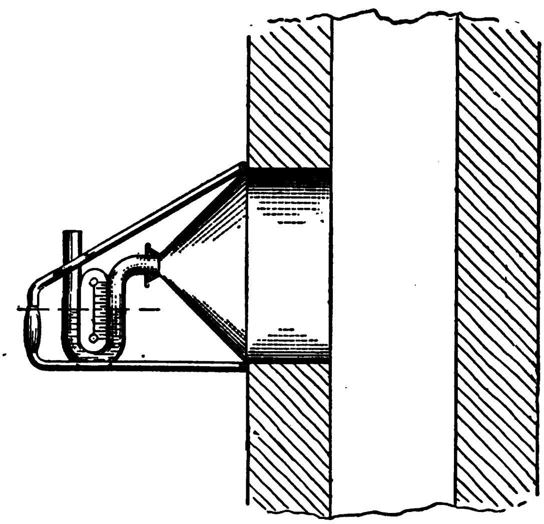


Fig. 7—Portable Draft Gauge with Funnel.

A column of water 28 inches high (or to be exact, 27.77) is the equivalent of one pound presure.

In reading the testing gauge the difference in height between the two columns should be noted. If a chimney draft was balanced by a column of water one inch high the strength of the draft would be 1/28 of a pound per square inch of area. The chimney draft of a good flue will equal at least .2 of an inch of water, as shown by the scale.

If a bent glass tube cannot be procured, or if the heating contractor cannot bend a tube, a draft gauge as illustrated by Fig. 8 may be made of straight pieces of glass tube and some short pieces of rubber tubing. A small piece of iron pipe is inserted into the smoke flue and the draft gauge attached as shown.

The following table compiled by a standard authority may be used in connection with the testing gauge:

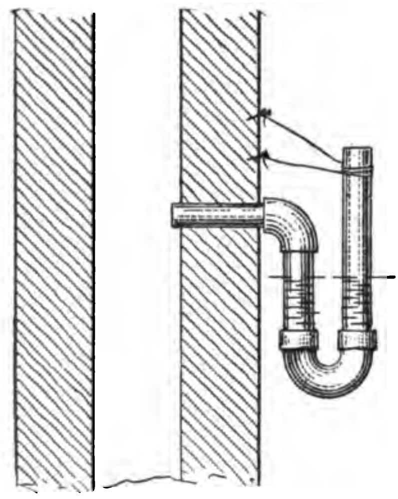


Fig. 8—A Simple Draft Gauge Easily Constructed.

Height, water, in inches.	Pressure in lbs. per sq. ft.	Velocity, ft. per sec.	Velocity, ft. per min.
.1	.521	15.05	903
.2	1.042	21.3	1278
.3	1.563	26.06	1564
.4	2.084	30.1	1806
.5	2.605	33.6	2016
.6	3.126	36.8	2208
.7	3.647	39.8	2388
.8	4.168	42.5	2550
.9	4.689	45.1	2706
1.0	5.210	47.5	2850
1.1	5.731	49.9	2994
1.2	6.252	52.1	3126
1.3	6.773	54.2	3252
1.4	7.294	56.3	3378
1.5	7.815	58.2	3492
1.6	8.336	60.2	3612
1.7	8.857	62.0	3720
1.8	9.378	63.8	3828
1.9	9.899	65.6	3936
2.0	10.420	67.3	4038

The area of a flue must be determined by measurement, as no form of testing will give the requirements, which are determined by the work in hand. The size of furnace to be connected with the flue determines the area required.

Suppose a furnace with an 8-inch smoke outlet is required. An 8 inch pipe has an area of 50.265 square inches, and under the most favorable circumstances of draft a round flue less than 8 inches in diameter or a square flue 8×8 inches in size should not be used. If a rectangular flue is provided, the narrow sides of the same should not be less than 8 inches.

The following table of flue areas will serve as a guide to flue construction, it being assumed that the chimney is from forty to sixty feet in height, or such as would be used for a two or three story building:

TABLE OF FLUE SIZES.

Equivalent cubic feet of space to be heated.	Round tile, standard sizes.	Rectangular tile, standard sizes.	Brick, inside dimensions.
10,000 to 15,000	8 in.	8½ x 8½ in.	8 x 8 in.
15,000 to 25,000	10 in.	8½ x 13 in.	8 x 12 in.
25,000 to 40,000	12 in.	13 x 13 in.	12 x 12 in.
40,000 to 75,000	16 in.	13 x 18 in.	12 x 16 in.
75,000 to 125,000	20 in.	18 x 18 in.	16 x 16 in.
125,000 to 200,000	24 in.	18 x 20½ in.	16 x 20 in.

When soft coal is used as fuel, 25 per cent. should be added to the rated size of flue.

Location of the Chimney.

We have previously mentioned city built houses and the character of their construction; in connection therewith there is another point which should be considered in providing the chimneys. They are usually built in the party wall separating the parlors or front rooms and the custom in this respect frequently locates the flue but ten feet or less from the front wall of the building. No matter in which direction the house faces the chimney will be found in the same location. Suppose the structure be five rooms deep; it may extend from eighty to one hundred feet from front to rear wall. Again, suppose the house faces the south, the chimney being within ten feet of the front wall; it is then necessary to run the warm air pipes from fifty to seventy feet toward the north, a condition beyond all reason to insure satisfactory and economical service.

The chimney should be centrally located, to the north and west rather than to the south and east in order that the longer warm air supply pipes may extend to and serve rooms

on the south and east sides of the building, and the shorter and more direct pipes to those rooms on the north and west sides of the building.

If possible to do so, it is well to erect the chimney up through the center of the building where the greater part of it will be surrounded by warm air, or rooms which are heated. In such a flue the smoke will not condense so rapidly, nor the gases cool as quickly as in a chimney built in an outside wall. When a chimney flue is erected in an outside wall it should be two bricks thick on the outside and, if possible, should be provided also with an air space between the bricks, as illustrated by Fig. 9. This air space should be closed and sealed at the roof line.

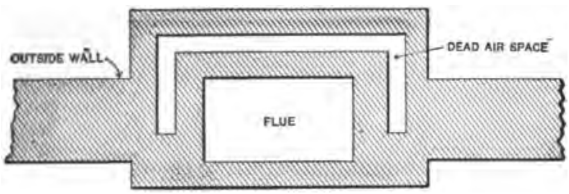


Fig. 9—Air Space on Exposed Side of Chimney.

The flue for use of the heating apparatus should have no other openings than that at the top and that for the smoke pipe. It should extend from twelve inches to two feet below the smoke pipe opening in order to provide a pocket for the soot.

We have called attention to the fact that the smoke and other products of combustion ascend the chimney flue spirally, and therefore a round chimney is the best form of chimney construction. Next in efficiency is the square flue, and last the rectangular flue.

Common Sources of Trouble.

In connection with the construction of the chimney, there are some points which should have careful attention of the architect and owner as well as the heating contractor.

Make the foundation for the chimney sufficiently solid and strong to support the weight of it. We have known chimneys having two flues to settle and break an opening between the flues, thereby destroying the draft, as illustrated by Fig. 10.

Beware of chimney tops. As a rule not more than one in ten of the chimney tops offered for sale is adequate in size or will improve the work of the flue. A chimney is only as

large as its smallest area, and an 8×8-inch flue (64 sq. in.) having a top 7 inches round (internal diameter) has but 38.48 sq. in. of area.

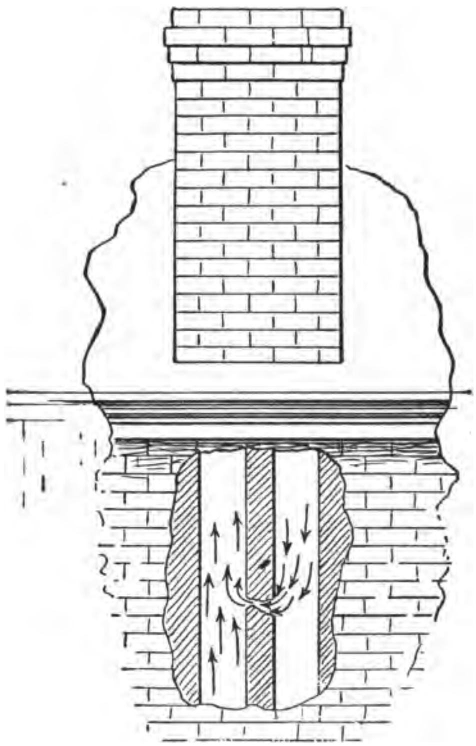


Fig. 10—Partition Walls between Flues Frequently Crack and Spoil the Draft.

Abrupt offsets should not be made, as flues of this nature clog with soot. The contractor should be careful to make the smoke connection of the size called for by the furnace, and should not reduce the pipe to save breaking out and enlarging the smoke pipe hole.

Chimney Flue Troubles.

Chimney flue troubles are many, and when there seems to be sufficient height and area look for trouble from one of the following sources:

(a) The smoke pipe may protrude so far into the flue as to cut off the draft.

(b) The chimney may be contracted or enlarged at some point. A chimney is only as large as its area at its smallest point. An enlargement at some point frequently acts as a damper to reduce the velocity of the draft.

(c) Loose clean-cut doors, open space around smoke pipe collar, or cracks in the flue admit cold air and spoil the draft.

(d) There may be openings in the flue for other smoke pipes besides that provided for the furnace. A flue for use of a heating apparatus should not serve for any other purpose.

(e) The flue may be plugged with soot or filled with rubbish. Birds build nests in chimneys, and falling plaster and soot may jam in the flue, particularly if there is an offset in the chimney. Two or three pieces of brick tied in a burlap bag drawn up and down the flue by means of a rope is a good method of cleaning it of soot or other obstruction.

These are some of the ordinary sources of trouble with chimneys, and while there are others they are not sufficiently common to cause frequent trouble.

A good flue is a delight to the experienced heating engineer and contractor, while a poor flue is a bane to him and a source of trouble and expense to the owner of the building.

CHAPTER II

THE FURNACE

Having determined that the chimney flue is adequate for the requirements demanded of it and that its location, if possible, is at such a part of the building as to prove most efficient, let us now consider the heart of the system; the furnace proper.

History of the Furnace

The hot air furnace was the original form which developed the later date methods of heating, and its advent, or we may possibly say its invention, was the direct result of necessity. Probably many of our readers know the story of the introduction of the furnace; nevertheless the telling of its history is interesting enough to bear repetition. The open fireplace had been found to be extravagantly wasteful of fuel and inadequate to properly heat the exposed parts of a room. The fireplace heater and later the stove were evolved to prevent this waste and to make possible a means to locate the source of the heat where it would prove most effective.

With the growth of the country, the forests were cut away. As towns and cities grew in size, the cost and inconvenience of obtaining fuel, and the further fact that this centralizing of business and the people, demanded larger and larger buildings to accommodate the conditions, made it imperative that some method should be produced whereby the labor of attending so many fires could be overcome.

This led to the invention, if it may be called so, of the hot air furnace, which in its early stage was nothing more than an extremely large stove encased in brick combining, in a measure, the principles of Dr. Franklin, who in 1744 invented the wood stove, with the hollow back or casing, having an air duct or cold air tube through which air from outside the building was heated and introduced into the room in which the stove was located.

The discovery and use of anthracite coal as a fuel proved a great factor in developing the possibilities of furnace heating. The early development of the furnace was largely the result of experimenting by Mr. Henry Ruttan. We are aware that many of the older manufacturers of warm air heating

apparatus have a sort of "me too" argument in this direction. It is certain, however, that when Mr. Ruttan in [illegible] wrote the following words, he expounded the true principles of furnace heating and ventilation, principles we cannot neglect if we are to meet with success in our work.

Mr. Ruttan said: "If you open your aperture at the top, and the air you bring in is warm, or if you open the aperture at the bottom, and the air you bring in is cold—in either case

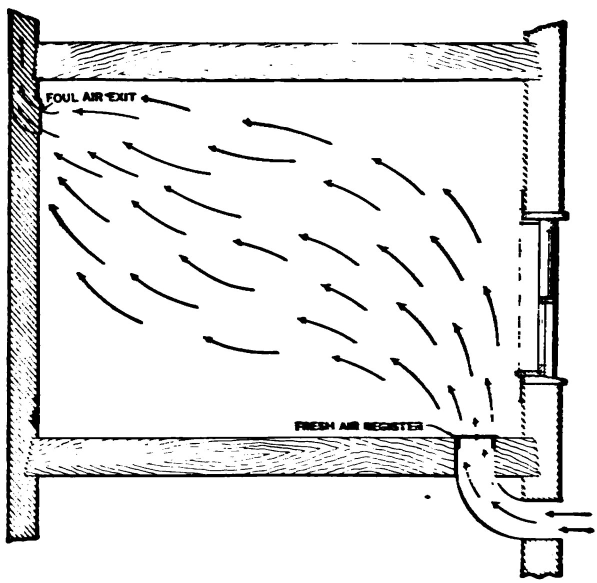


Fig. 11—To Ventilate and Cool a Room.

the body of air will not budge; your warm air will go through the body, straight to and out of the top aperture; and the cold air will do the same through the bottom aperture. The consequence is easily seen—you will neither warm, cool, nor ventilate the room."

"If you want to ventilate your room to warm it, and open the bottom aperture, you will succeed in both; because the fresh air will be the warmest, and will not stop until it comes in contact with the ceiling, where spreading out in a level strata over the whole ceiling, it will keep its relative position to the whole body until it reaches the bottom and passes out through the aperture. If we want to ventilate our room to cool it, we must let the air out at or near the top.

"If on the other hand, we wish to ventilate our house to warm it, we must take the air out at or near the bottom, thus keeping up a continual exhaustion of the heated air; and if we wish to set the whole body of air in the room in motion, upward or downward, we must, of course, bring in the necessary amount of outside air to do it."

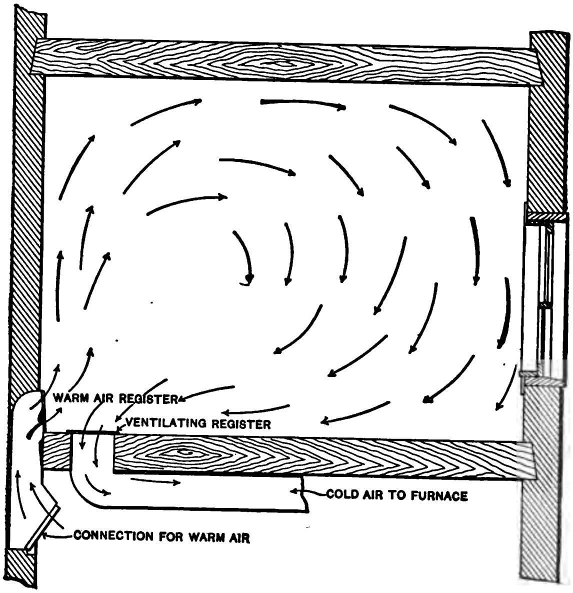


Fig. 12—To Ventilate and Warm a Room.

Figs. 11 and 12 illustrate these principles, and to those who are making a study of this subject we recommend that they fix them indelibly upon their minds, as they combine the true principles governing hot air heating and ventilation.

Character and Size of the Furnace.

It is not our purpose to comment on or advocate any particular type of furnace, except in a general way to note such distinctive features as will assist the furnace man to make the proper selection for any work in hand.

The bricked-in furnace has been succeeded by the more up-to-date portable setting, or casing, and except in very old buildings the former style of furnace is seldom seen.

The grate is a very important part of a furnace. Enough open space should be provided to permit the passing of sufficient air to meet the requirements when re-charging with

fuel, and the bars should be strong enough to carry the heaviest load without sagging or binding.

Beware of cheap furnaces. They are expensive at any price. A few dollars saved in the price of the furnace itself must result in the furnishing of lighter castings, a smaller capacity, less radiating power, and cheaper construction throughout.

In a good furnace there will be from twenty-five to thirty square feet of heating surface to one of grate surface. There should be a deep fire pot, and a grate of sufficient area for the work in order that the rate of combustion will not exceed four pounds of coal per square foot per hour in coldest weather. Definite rules will be given later for ascertaining the proper size of furnace and grate area.

The gases in the combustion chamber must not be cooled by allowing the cold air to come in contact with the outside of this chamber. A furnace does its best work under conditions of perfect combustion, and one so constructed that the incoming cold air will be partially tempered by the flue gases in their exit from the furnace before coming in contact with the hot plates of the combustion chamber, will show a higher rate of efficiency per square foot of grate surface than will a furnace in which the cold air passes immediately over the hot plates or heating surfaces.

If the chimney flue is of sufficient size and is properly constructed, a temperature within it of 300 degrees will be more than adequate for perfect draft. The excess of fuel required in many furnaces is due not only to poor combustion, but to the escape, at a high temperature, of the gases into the chimney flue. By bringing the cold air into contact with the heat of these gases much of this lost heat may be utilized and saved. In the construction of the furnace the joints should be gas proof and dust proof under all circumstances.

Furnace Casing and Top.

All furnace casing should be made double with an air space between the inner and outer casing sufficient to act as a non-conductor and keep the outer casing cool. Asbestos paper or mill board is frequently placed between these two casings, or as a covering for the outer one. This is not a necessity, however, providing there is sufficient air space between the inner and outer casing. Our preference is for a black iron inner casing and a galvanized iron outer casing. No single cased furnace will do good and economical work.

There are many opinions as to the proper style of top or bonnet. The style used may be in a measure dependent

upon the height of the cellar, or the manner in which the leader pipes are attached. Any one type of top is not adaptable to all cases. Fig. 13 illustrates a straight side flat top, having a hoop or iron band around the top to hold about one inch of sand. A deflector is placed on the inner side as indicated by the dotted lines. The leader pipes are taken off, back of or on the inner side, of the deflector.

Fig. 14 shows a common form of pitch top to which the leaders are connected by bevel elbows. Unless a deflector is

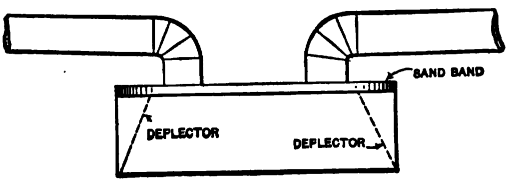


Fig. 13—Straight Side Flat Top Bonnet.

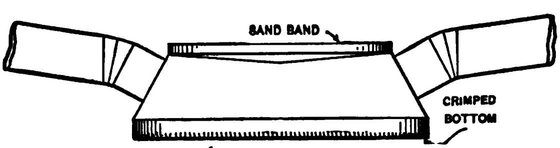


Fig. 14—Common Form of Pitch Top.

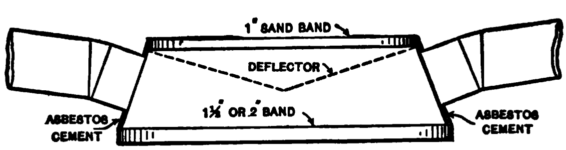


Fig. 15—Desirable Type of Bonnet.

used the hot air will short-circuit into the shorter and more direct leader pipes.

Fig. 15 illustrates what we believe to be the very best type of top. The deflector has a deep pitch toward the center. Above this the top is flat, having a one-inch sand hoop around the edge. The bottom is provided with a similar hoop one and one-half or two inches wide which fits tightly over the furnace casing and protrudes slightly above the upper edge. After the openings for the leader pipes are cut in and the pipes attached, the remaining portion of the pitched side of

the top is covered to the depth of one inch with plastic asbestos cement. This is supported in position by the extension of the iron band fastening the top to the casing. The casing being double, the top of the hood being protected by sand, and the sides of the top protected with asbestos cement, there can be no loss of heat from the furnace.

All leader pipes should leave the top at the same level and should be properly aligned. The careful alignment of them makes not only a better looking job, but a better working one as well. Do not take the leader pipes from the top and from the side on the same job. Air will move toward the point of least resistance, and heated or expanded air will move vertically through the nearest aperture; therefore the leader pipes taken from the top will rob those taken from the side.

We know a furnace man who thinks it best to take the longer runs from the top and the shorter runs from the side, and strange to say he has considerable success. Human ingenuity, however, is many times a failure, and we prefer to stick to methods, which have proven successful.

Location of the Furnace.

In locating the furnace many of the details entering into the construction of the building, such as the position of the piers or posts supporting girders, the position of division walls, of the chimney flue, etc., must be taken into consideration. When the north and west sides are well protected from the prevailing winds of the winter season, the furnace should set as near to the center of the building as conditions will allow. When the building is exposed on all sides the furnace should be placed more to the north and west of the center, and, provided the chimney has been built in accordance with our suggestions given in the second article of this series, this location is made available without the use of a long smoke pipe. Under ordinary conditions the furnace should set not more than 6 feet distant from the chimney flue. The warm air pipes supplying the rooms to the north and west, or to the principal rooms on the first floor, should be as short as possible. It is far better to double the length of the smoke pipe, if necessary, to locate the furnace to the north and west, than it is to double the length of the warm air pipes, if contingencies arise which make it imperative to select between the two courses.

Methods of Setting.

We are aware that many of those engaged in the business of installing furnaces have their individual opinions as to the correct method of setting a furnace. However, while we

respect such motives it would seem to the writer that some furnace men are inclined to stick to certain methods and principles simply because they have had more or less success in one particular direction by following the usual method. The up-to-date furnace man should permit existing conditions to shape the method of setting the furnace, and he should be competent to judge what particular method of the number in vogue is best suited to the job in hand. Some furnace men are careless in their methods of preparation for the installation of a furnace, frequently setting the furnace directly on the dirt cellar bottom when it seems sufficiently hard to support its weight. This method results in a source of dirt and dust. The heat in the ash pit will dry out the earth so that the jarring, incident to attending and shaking down the fire, will cause particles of dirt to be carried upwards and into the rooms by the air currents passing through the furnace.

The best practice is to build a cold air pit under the furnace, such as is illustrated by Fig. 16. The brick pier shown in the center will support the weight of the furnace and assist in dividing the cold air supply. Note that a corner of the pier is toward the cold air duct, thus allowing an equal distribution of the cold air to each side of the furnace.

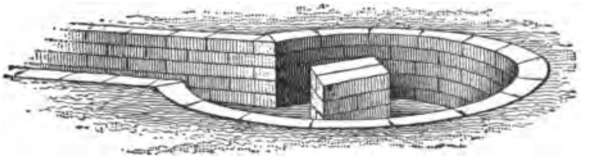


Fig. 16—The Cold Air Pit.

The pit should not be less than 12 inches nor more than 16 inches in depth. In building it a place should be excavated of sufficient depth to allow a filling of broken stone or brick about 4 inches deep. This should be covered by a layer of coarse sand and cement, leveled and well tamped down. The floor of the pit, which is also the foundation for the wall and pier, should be constructed of brick laid in cement and plastered smooth. This may add a trifle to the cost of installation, but will prove in the end to afford the most satisfactory job.

Frequently, because of the low location the building occupies, there is trouble from water if excavation is made below the surface of the cellar floor, and in such cases the air duct must be connected to the furnace above the floor level.

For this purpose a special type of casing must be used, as illustrated by Fig. 17. The frame of the opening shown is called a shoe. Do not connect the cold air into a shoe on one side of the casing only, as this style of connection will not afford sufficient air to the opposite side of the furnace, as the

Fig. 17—Casting for Use when Cold Air Duct is Above Floor.

air space through the furnace bottom around the ash pit and fire pot is shaped very much like a horseshoe, as seen in Fig. 18. The shoe should be placed at the rear, or, what is better, a sparate opening or shoe should be provided for connecting the air into either side.

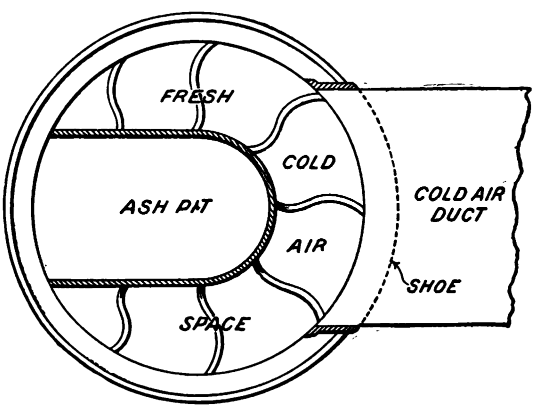


Fig. 18—Proper Location of Shoe for Cold Air Duct.

Care should be exercised in setting a furnace to carefully cement or pack all joints where they are necessary, and the casing should be fit absolutely air tight. Loose joints in the furnace castings will allow dust and gas to enter the warm air distributing pipes, and a leaky casing interferes with the proper working of a furnace precisely in the same manner as a leaky chimney interferes with the draft.

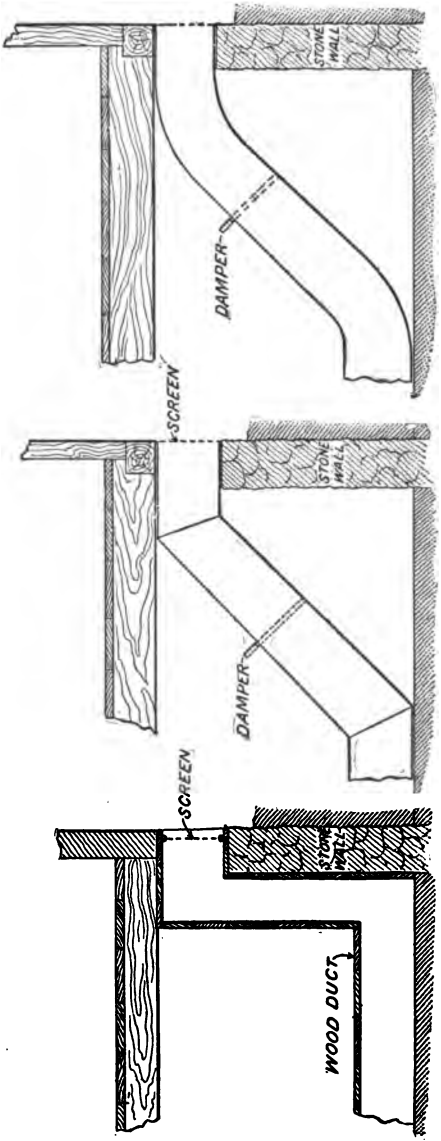


Fig. 19—Three Methods of Supplying Cold Air.

The furnace must set sufficiently low to insure giving the proper pitch to the longest warm air pipes, and, if necessary to secure this desired feature, the furnace may be placed in a pit. When conditions make this course essential, build the pit of ample size and allow plenty of room for setting the furnace. Sufficient space should also be provided in the pit at the front of the furnace to facilitate the removal of ashes and the work of attending to the apparatus.

The Cold Air Supply.

The furnishing of an adequate amount of cold air, together with a proper manner of supplying the furnace with it, is no doubt the key to successful hot air heating, and we can therefore consider this the most important part of furnace installation. An inspection of present day furnace work in some localities would in ninety-nine jobs out of every hundred either show no provision whatever for an outside cold air supply or, if provided, it would be an ill-shaped or leaky duct made of rough boards. It is just as important to eliminate all possible friction from the movement of the cold air as it is to provide easy movement of the heated air. Where a galvanized iron duct is attached, curved elbows should be used rather than miter elbows, and the cold air pipe should drop to the floor at an angle instead of pitching down vertically.

Fig. 19 shows three methods of supplying cold air, the sketch on the left illustrating a common type of wood boxing frequently found on cheap work. The center illustration shows a duct made of galvanized iron, a marked improvement over the former, which can be still further bettered, however, by the use of curved elbows, as shown on the right. This latter type of duct may be easily connected to an underground tile, and, when provided with a cold air chamber or air cleansing box on the inside of the opening through the cellar wall, it makes an admirable method of handling the fresh air.

In towns or cities where trouble is experienced from dust or soot laden air, it is advisable to filter or cleanse the supply by means of cheesecloth baffles. There are numerous plans of using these cleansing baffle cloths, but only one general method. The outside air upon entering the basement flows into a cold air chamber, striking at a sharp angle a series of filter screens partially covered with cheesecloth, which are set in the cold air chamber at such an angle that the incoming supply is compelled to make a number of right angle turns in passing the baffles. The chamber should be assembled in such a manner that one side (in the form of a door) opens to permit the ready removal of the screened

frames for cleaning. Do not use starched muslin or cloth of smooth texture for this purpose. The rougher the surface of the cloth the better will be the results obtained. Some recom-

Fig. 20—Air Filter Having Cloth Baffles.

mend that the cloth screens be coated with oil to assist in collecting the dust, but we have found cheesecloth well suited to the purpose without such a coating.

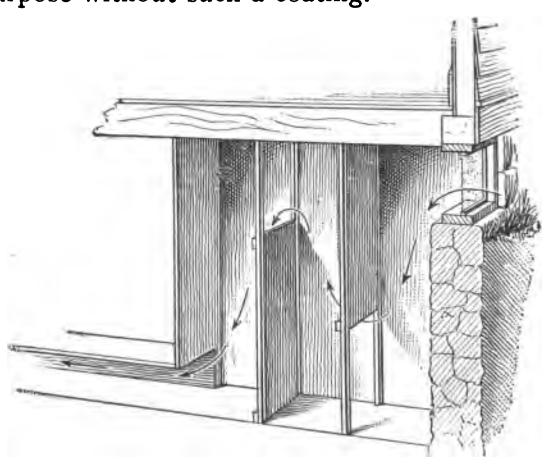


Fig. 21—Air Filter Having Wooden Baffles.

Another style is made of permanent wood baffles so arranged that the first one next to the fresh air inlet acts as a deflector, precipitating a large portion of the dust to the bottom of the box or chamber.

The two styles are illustrated in Figs. 20 and 21, using for illustration that recommended by prominent furnace manufacturers, which method cannot be too highly commended. These screens not only filter the supply, but also act as a damper to control the velocity of the incoming air before it enters the cold air duct. As the inlet for cold fresh air should be on the north or west side of the building it is necessary to make some provision for controlling the velocity of the prevailing winds of winter, and this, as well as the cleansing of the air, is accomplished by the method illustrated.

The cold air from outside the building should enter the furnace through the pit. The recirculated air should be connected to furnace by attaching the piping to shoes on either side of the casing, or, if necessary to connect the inside cold air ducts into the main cold air supply, they should enter this duct in such a manner that there will be no possibility of the cold air entering the circulating ducts. Fig. 22 illustrates one method of accomplishing this result.

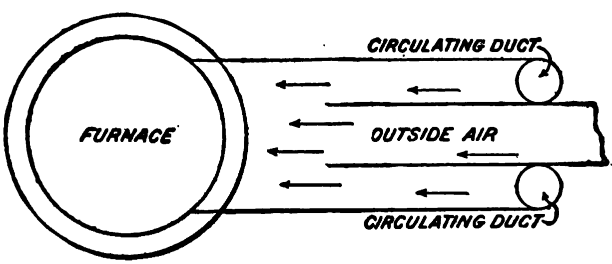


Fig. 22—Combining Recirculated Air with Cold Air.

Some furnace men claim that all ducts, both outside and inside, should be arranged with dampers so that one or the other system only may be used. Our experience has been that occupants of a building will not give the required attention to dampers, or, if they attend to them at all, will not do so properly. We therefore recommend the connection shown by Fig. 22 which should be installed without dampers of any kind other than a single one by which the outside cold air can be entirely shut off when a recirculation of the inside air only is desired. It is understood that the outside cold air is taken from a cold air chamber, which will control the flow of air in windy weather and which is not directly connected to the outside.

In area, the cold air duct should be three-quarters that of all of the warm air pipes leading from the furnace top. We think this rule is very generally known among furnace men, and, while not absolutely accurate, is sufficiently so

for all purposes. These conditions do not hold in figuring the capacity of the ducts for recirculation of the inside air. These ducts should be equal in area to the warm air pipes, or nearly so.

To arrive at the proper size of the cold air duct we figure on the expansion of the outside air when heated to a normal degree. For the recirculating ducts we figure on the quantity of air delivered by the warm air pipes, which, after supplying heat to the various rooms, is not cooled sufficiently to make any considerable depreciation in its bulk or volume.

Size of Furnace Required.

The furnace man is held responsible by the furnace manufacturer for most of the trouble and for the largest share of the present condemnation of the furnace and of warm air heating. Are the trade justly open to criticism or are the manufacturers at fault? This question is of interest to every person who desires to see this class of heating work elevated to a higher standard.

The furnace man is at fault in adopting methods necessitating cheap competitive work. The manufacturers are, however, the chief offenders. Before proceeding further permit us to insert a word of praise for those manufacturers who are giving definite information to the furnace man as to the ratings of their furnaces, best methods of installation, etc., and who are placing conservative ratings on their goods. We think it is not stating the case too strongly when we declare that one-half the hot air furnaces produced are grossly overrated.

If furnace heating is to be placed on the higher plane it deserves there are many manufacturers who must rate their furnaces on a more conservative basis. The practice of determining ratings on the basis of casing sizes must be discontinued. All methods of figuring capacities that do not take into consideration the cooling surfaces of a building—*i. e.*, the heat losses through glass (windows), outside doors and walls—when computing the necessary size of furnace, must be abolished if we are to meet with success.

Last, but not least, the evil practice of selling furnaces to any one who has the money to buy and pay for them, without regard to the purchaser's fitness and ability, or to his knowledge as a furnace man, must cease if clap-trap methods and cheap competition are to be overcome. If the past practices are allowed to prevail we shall reach that stage where the owner will refuse to pay for his furnace until he has had at least one winter's trial of the apparatus and assured himself of its satisfying qualities.

We shall not presume to dictate to manufacturers how they shall rate their furnaces. In view of the exigency of the case they should, however, adopt a basis by which all cooling surfaces of a building are reduced to an equivalent from which the schedule of the probable performance of the furnace can be made, and from which the furnace man can select the size suited to any purpose.

The heating surface of the furnace must be sufficient to warm the amount of air the cubical contents of the building will demand, and the air outside of the building is always cooler than the air within. It is a law of nature that the temperatures of adjacent bodies will equalize. A certain portion of the heat is diffused or lost by transmission through walls and windows; therefore the furnace must not only be large enough to heat the air within the building with from two to four changes of air per hour, but it must also have sufficient capacity to compensate for the losses by diffusion. The heat losses in two buildings are never the same and yet when reduced to equivalent glass surfaces or equivalent wall surface they are easily determined.

Manufacturers of steam and water warming apparatus have based their ratings on these factors and the steam fitter, by any one of a dozen rules, can determine accurately just what size of boiler is necessary for any particular requirement.

Let us see how readily this style of figuring may be adapted to the furnace. We will take for example a house 30 by 40 feet, having ten rooms to be heated. The house has twenty windows averaging 3 by 6 feet, and three outside doors 3 by 8 feet (including transoms). First floor ceilings are 10 feet, and second floor ceilings 9 feet high. The approximate cubical contents to be warmed would be:

$$30 \times 40 \times 10 \text{ plus } 30 \times 40 \times 9, \text{ or } 22{,}800 \text{ cubic feet.}$$

The glass surface (doors counted as glass) would be:

$$3' \times 6' = 18 \times 20 = 360$$
$$3' \times 8' = 24 \times 3 = \underline{\ 72\ }$$

Total glass surface............. 432 square feet.

The wall surface would be:

$$30 + 40 = 70 \times 2 = 140 \times 19 \text{ (height of ceilings)} = 2{,}660 \text{ sq. ft.}$$

Assuming, as we properly may, that 4 square feet of exposed wall equals 1 square foot of glass in cooling surface or heat loss, we have:

$$2{,}660 \div 4 = 665,$$

the glass equivalent of the wall surface, which, plus 432, the

square feet of actual glass, gives the total equivalent of glass as 1,097 square feet.

Let us figure on two changes of air per hour, and the total amount of air to be warmed hourly will be $22{,}800 \times 2$, or 45,600 cubic feet. The loss of heat by transmission through ordinary glass windows is determined as being approximately 0.8 B. T. U. (British Thermal Units) per square foot per hour, per degree difference in temperature, or, in other words, in this case the outside temperature being at 0° (zero) and the temperature of the rooms 70°, the difference, 70° — 0°, would be 70°; therefore,

$$1{,}097 \times 0.8 \times 70 = 61{,}432 \text{ B. T. U.}$$

We also know that one heat unit will raise 55 cubic feet of air one degree in temperature. Assuming that the hot air at the registers enters the rooms at 120°, we proceed as follows:

$$45{,}600 \div 55 \times 120 = 99{,}480 \text{ B. T. U.}$$

A good quality of anthracite coal contains approximately 14,500 heat units, of which about 10,000 are actually available for heating in a properly constructed furnace with a combustion of 3 pounds of coal per square foot of grate per hour; therefore, $10{,}000 \times 3 = 30{,}000$ B. T. U. per hour per square foot of grate.

To arrive at the correct size of grate to properly heat this house we add the required heat units, $61{,}432 + 99{,}480 = 160{,}912$, and divide by $30{,}000 = 5.36$ square feet. Therefore we require a grate having 5.36 square feet of area.

This is based on zero weather for the winter, and, judging from the present rating of some furnace manufacturers, they are taking long chances and are expecting mild weather the better part of the heating season.

CHAPTER III

PIPE, FITTINGS AND REGISTERS

Furnace fittings such as elbows, boots, offsets, tees, etc., are made in a great variety of shapes, the construction and patterns for which are treated by William Neubecker in the concluding portion of this book.

We desire particularly to call attention to some common errors and offer suggestions for their correction. In considering the question of piping a job of furnace heating, we should naturally suppose that the later day advanced methods were far superior to those used years ago. Investigation would reveal that in many respects this is true—also that in almost as many other respects it is not the case. The old plan, followed in the early days of warm air heating, of running round or square flues or risers, has not been improved upon up to this time in so far as good service is concerned. True, there have been marked improvements in the designs of boots, tees and register boxes, but are these improvements such that they have a bearing on the reduction of friction or on increasing the flow of air through the piping? We think that they concern principally the money end or cost of the work. The infinite variety of stock patterns of all kinds of furnace pipe fittings, such as adjustable elbows and the like, make it easier and quicker to install a job, but for all-around efficiency, give us the furnace work of the good old days, when round or square risers were used, when all joints were soldered and the fittings were shaped on the job, being made to conform to the conditions of the work.

The flow of air through piping is one of the first parts of the business that should be studied by the furnace man. The illustration, Fig. 23, represents a 12 inch diameter round pipe supplying a 3½ by 12 inch riser. Friction? Yes! and plenty of it. The flow of air in a pipe the area of which is 113 square inches is attempting to enter a pipe the area of which is but 42 square inches, or nearly two-thirds less in capacity. This shows a condition frequently found on present day furnace installations. Follow the effect of work of this character down to the furnace and it will develop that the principal results attained will be an

excessive coal consumption and a shortening of the life of the furnace due to an overheating of its castings.

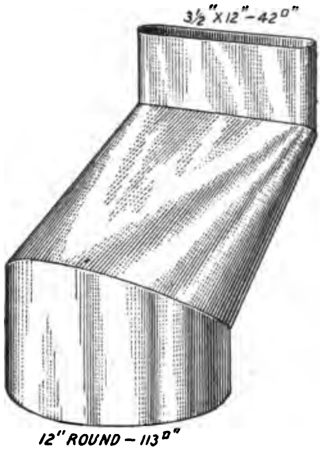


Fig. 23—Two Much Taper, Causing Friction.

How may this evil condition be avoided? This question naturally follows. And the answer is—by enlightening the architect as to its dangers, and at the same time having partitions provided in the buildings in which flues of suitable shape and area may be installed. Note by illustration, Fig. 24, such a partition furred out to accommodate two 8-inch round flues, one supply an 8 by 10-inch first floor register, the other feeding a second floor room. An 8 inch round pipe having an area of 50 square inches will give as good service as an 8 by 8-inch square pipe, although the area of the latter is 64 square inches. It will afford 30 per cent. better service than can be obtained from a riser 4 by 16 inches. In the average house the studding are set 16

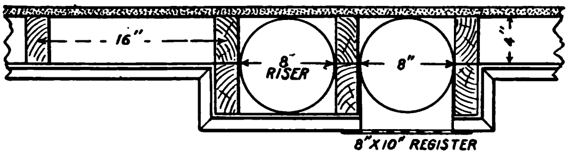


Fig. 24—Using Old Style Round Pipes.

inches on centers, and if 2 by 4 inch single studding are used, a riser 3½ by 14 inches will be the largest possible pipe that can be installed.

The new type of side wall register has offered an improvement in the method of supplying a first floor register and a riser from the same hot air pipe. Of this register we shall speak later. Of the boot, one type of which is illustrated in Fig. 25 we wish to say, that, after allowing the full width of the studding, the

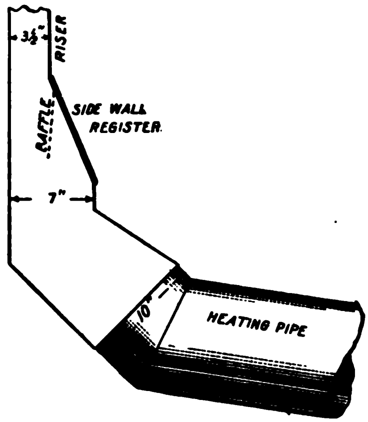


Fig. 25—Boot for New Type of Side Wall Register.

space usually occupied by lath, plaster and baseboard, together with about 2 inches of the floor, we can still use a riser 7 inches deep, which, when properly baffled, has the capacity to supply both register and riser.

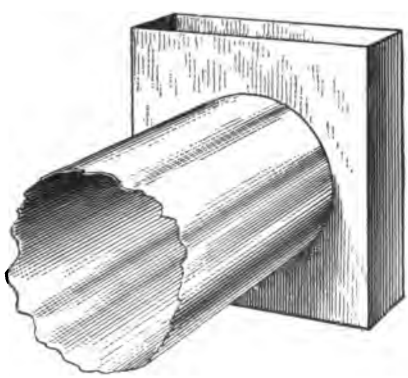


Fig. 26—Arrangement Causing Back Pressure and Friction.

On much of the cheap furnace work we find the riser extending below the cellar joists and the warm air or leader pipe connected to it at right angles as illustrated in Fig. 26 a practice

causing back pressure and friction. A homely illustration of this may be witnessed by turning the nozzle of a garden hose

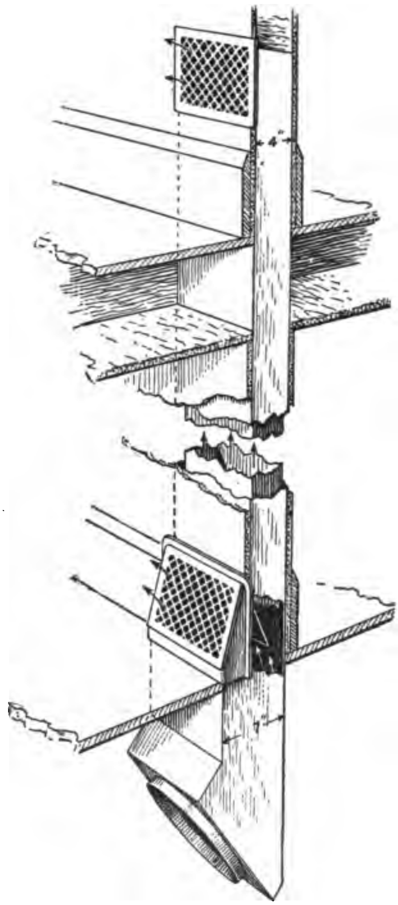


Fig. 27—Side Wall Register with Proper Boot and Double Pipe.

directly against a flat board first, and then setting the board at an angle of, say, 45 degrees. Note the difference in the flow of the water from the hose as it strikes the board. There is but one application proven by the experiment—transition boots are valuable, too valuable, in fact, to be dispensed with.

All risers of single pipe construction should be thoroughly covered with asbestos paper. Better than this, however, is the double pipe illustrated by Fig. 27 which also shows the installa-

tion of a side wall register and a proper type of boot for leader connection.

As to the size of the warm air or leader pipes, it does not seem necessary to write much, as the sizes of such pipes, and also the fact that they should be as direct and as short as possible, are well established and generally known to most furnace men. No leader should be less than 8 inches in diameter. First floor rooms, 12 by 12 feet to 16 by 16 feet, or similar in area, should have 9-inch leader pipes. For second floor rooms of equal size 8-inch leaders are sufficient. First floor rooms having an area equal to from 17 by 17 feet to 21 by 21 feet should have 10-inch leaders. Same size second floor rooms, 9-inch leaders. First floor rooms 22 by 22 feet to 28 by 28 feet should be supplied with 12-inch leaders, and for second floor rooms of similar size 10-inch leaders should be provided. Rooms in excess of this size had best be supplied by two registers and separate leader pipes. The above schedule is based on 10-foot ceilings for first and 9-foot ceilings for second floor. For extreme exposures or an abnormal amount of glass surface 15 to 25 per cent. should be added to the above areas according to circumstances.

In general the risers to second or third floor rooms may be 25 per cent. smaller than those for the first floor, as the velocity of air in a verticle pipe is approximately 25 per cent. greater than in a horizontal one.

The character of the construction of the building should be carefully considered in determining the size of any part of a hot air heating system. The infiltration of cold air around loose windows and doors, and the loss of heat through poorly constructed walls, should have an influence when determining sizes, and the delivery of a surplus amount of air at a correspondingly lower temperature to the various rooms means economy in the consumption of fuel and longer life for the apparatus.

Size and Location of Registers

The proper locating of the registers on a job of warm air heating has much to do with the perfect distribution and the free circulation or passage of the air—conditions which contribute so largely to the successful operation of the system. Improper location and incorrect size of registers insure partial if not total failure.

Registers will allow of a discharge of air equal to the full amount of the net air capacity only when situated along or in the inner wall of the room in which they are placed. Fig 28 shows a small floor plan, the dotted lines indicating the exposed portion of the room, which is that outside these dotted lines. The warm air registers may properly be located at any point on

the inside of the lines for good service. However, there are some conditions which a wise judgment on the part of the furnace man will caution him to note and provide for. One such condition is the placing of a register as far as possible toward the north and west on the inside of a room, as warm air can be delivered toward the north more easily through a basement

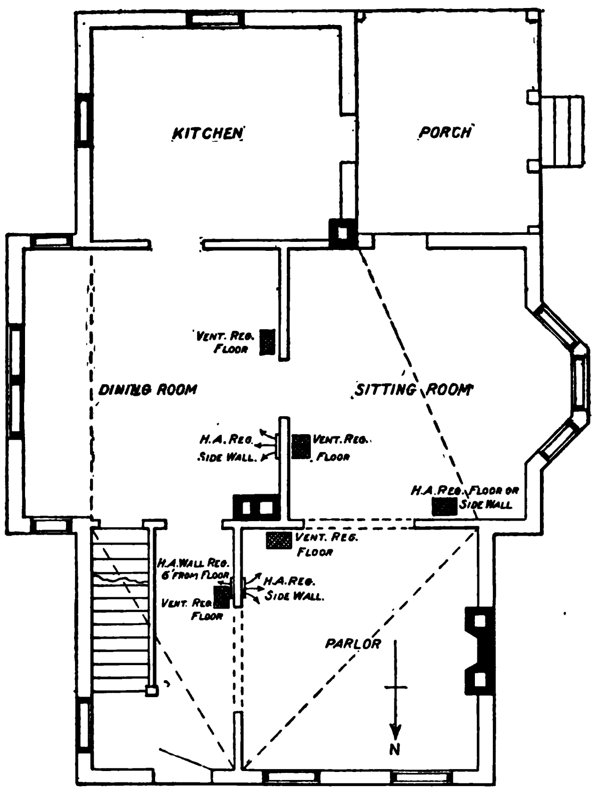


Fig. 28—Plan Showing Location of Registers.

leader pipe than it can be circulated toward the north in the room itself. The location of the registers on Fig. 28 illustrates this principle.

The register in a staircase hall which opens into the second or third floor halls should be placed about six feet from the floor in the side wall, the circulating register being located in the floor at a point immediately below the warm air register.

Where a long room is exposed on either end, such as a parlor

in a city-built house, or a house erected in a solid block, the registers may be located at each end of the mantel, as shown by Fig. 29.

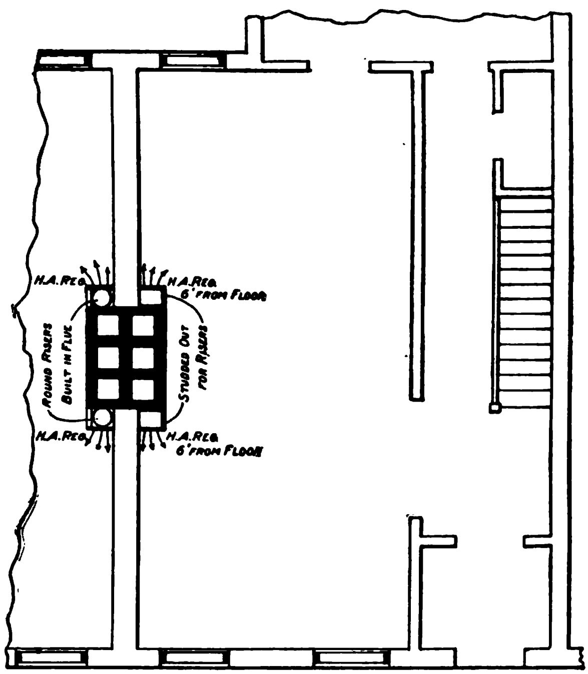


Fig. 29—Location of Risers in City Building.

The risers may be built in the brickwork or, if necessary, they may be encased in studding at either end of the chimney breast. This will permit of the use of round risers, which should serve the registers located about six feet from the floor; and the very best results will be obtained by setting them in this manner. It is well to use two circulating registers located as shown on sketch.

In figuring the capacity of registers it is well to allow 50 per cent. of the fret-work size. We are aware of the fact that many manufacturers claim to make registers of which two-thirds the fret-work size is net air capacity, but many of such are over-rated. More errors of judgment are committed through underestimating than through overestimating the size of registers.

The following table is submitted as a guide and is based upon ordinary conditions of exposure:

Size of room.	Size of leader pipe.	Area of riser.	Size of register.
8x 8 ft. to 9x12 ft.	8 in. 1st floor	40 sq. in.	8x10 in. to 8x12 in.
	8 in. 2nd floor		8x 8 in. to 8x10 in.
10x12 ft. to 12x14 ft.	9 in. 1st floor	48 sq. in.	10x12 in. to 10x14 in.
	8 in. 2nd floor		8x10 in. to 8x12 in.
14x16 ft. to 16x20 ft.	10 in. 1st floor	56 sq. in.	10x14 in. to 12x14 in.
	9 in. 2nd floor		8x12 in. to 10x12 in.
20x20 ft. to 20x24 ft.	12 in. 1st floor	75 sq. in.	14x16 in. to 16x20 in.
	10 in. 2nd floor		12x14 in. to 14x16 in.

CHAPTER IV

INSTALLATION OF THE FURNACE

There is something fascinating in the construction of a first class piece of work, whether it be an intricate piece of mechanism, a handsome and well-appointed home, or a heating apparatus installed to properly warm the same; therefore we may well say that we have now reached a highly interesting and attractive portion of our discussion of progressive furnace heating, namely, that of considering the practical, as well as the theoretical, side of actual furnace installation.

We shall aim to approach the subject from the very beginning, starting with the actual planning of the heating apparatus, and for illustration will consider a good-sized suburban home, exposed on all points of the compass. Fig. 30 shows the first floor of the building, the rooms to be warmed being the Parlor, Living Room, Library, Dining Room, Reception Hall and Rear Entry. Fig. 31 shows the second floor, consisting of a Den and Alcove, four Chambers, Bath Room and Hall, making a total of fourteen rooms to be supplied with heat.

The first heating system we will consider will be one in which no provision is made for any ventilation further than that ordinarily obtained from a properly constructed hot-air furnace installation.

Assuming that a chimney flue of good construction and adequate area has been provided in the proper location (as is the case for the residence illustrated), the first step is to suitably tabulate the information necessary to enable the construction data to be figured. We refer by this to the size and location of the various rooms, the number and size of windows (glass area), counting outside doors as glass surface, and the amount or area of all outside exposed wall for each room. As we have stated before in these articles, the only correct method for determining furnace capacity involves a consideration of the various cooling surfaces of a room or building.

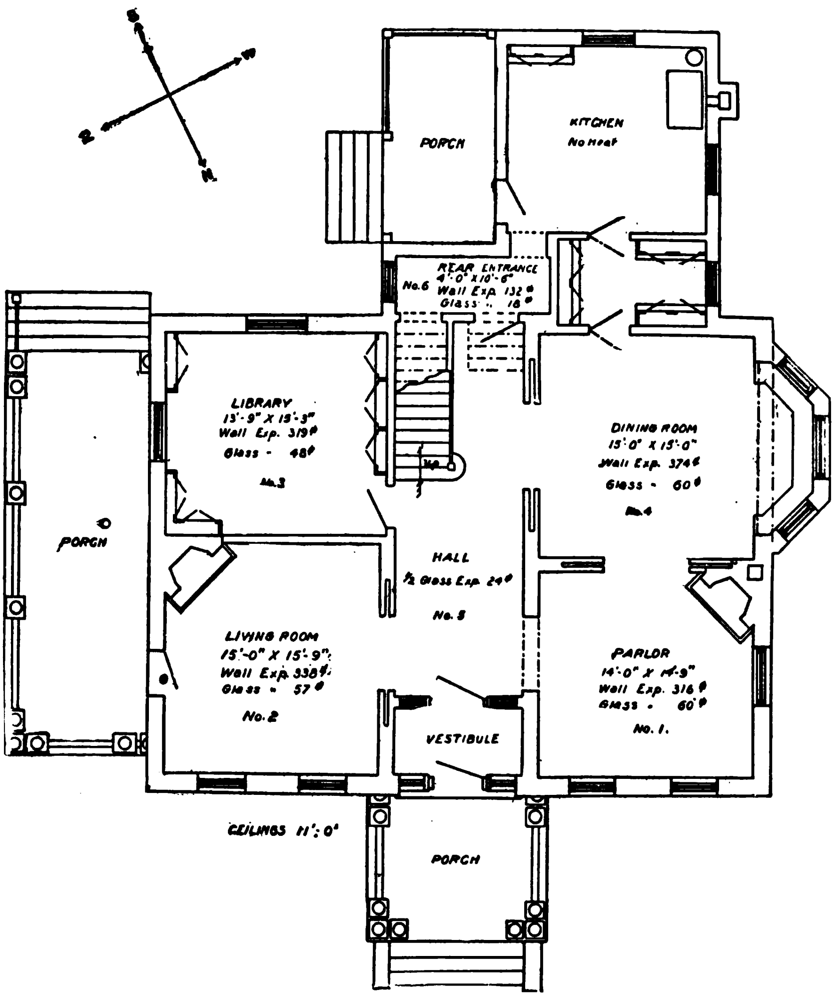


Fig. 30—First Floor Plan, Giving Square Feet of Wall and Glass Exposure

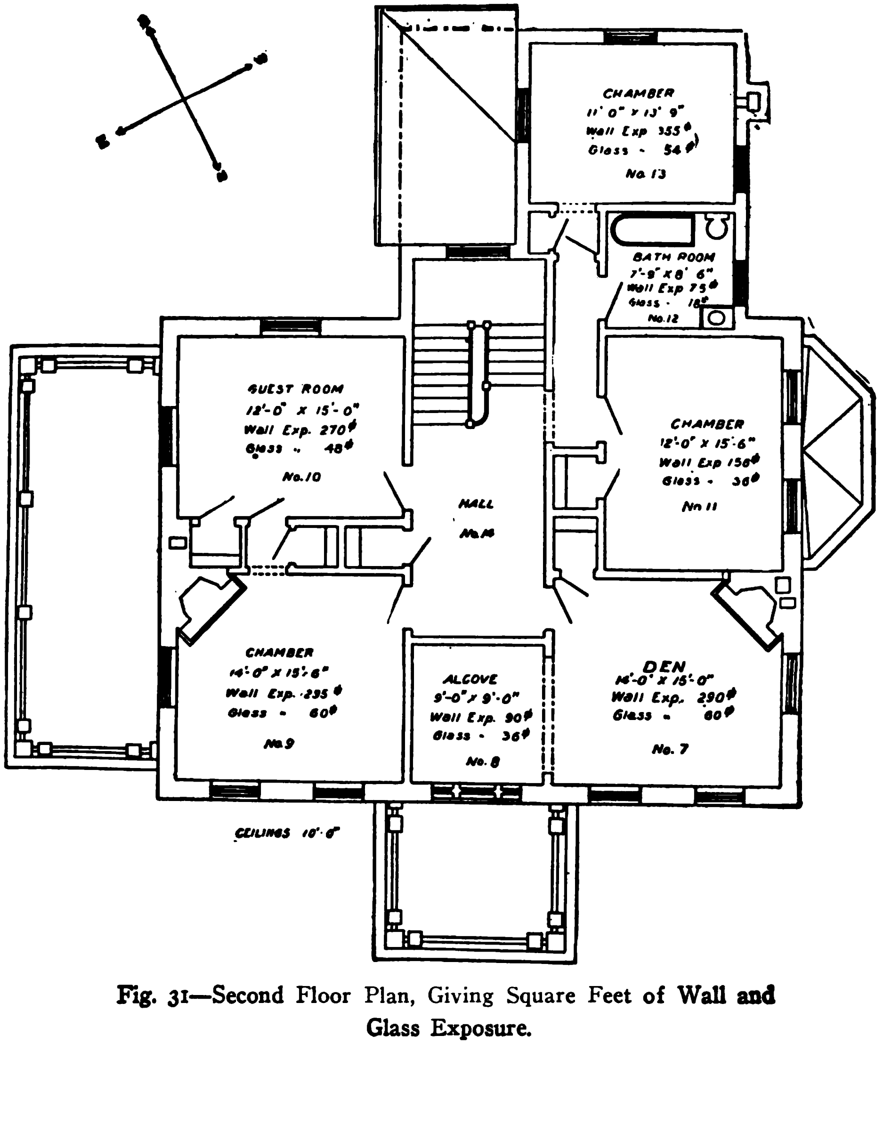


Fig. 31—Second Floor Plan, Giving Square Feet of Wall and Glass Exposure.

This tabulated information follows, and for convenience all rooms are numbered.

Room.		Size.	Cubic feet.	Sq. ft. of exposed glass.	Sq. ft. of exposed wall.
No. 1	Parlor	14′9x14′ x11′	2,244	60′ N. & W.	316
" 2	Living room...	15′ x15′9x11′	2,607	57′ N. & E.	338
" 3	Library	15′3x13′9x11′	2,310	48′ S. & E.	319
" 4	Dining room...	15′ x19′ x11′	3,135	60′ W.	374
" 5	Reception hall..	9′ x25′6x11′	2,519	24′ N. (½)	None
" 6	Rear entrance..	4′ x10′6x11′	462	18′ E.	132
" 7	Den	14′ x15′ x10′	2,100	60′ N. & W.	290
" 8	Alcove	9′ x 9′ x10′	810	36′ N.	90
" 9	Chamber	14′ x15′6x10′	2,170	60′ N. & E.	295
" 10	Guest room	12′ x15′ x10′	1,800	48′ S. & E.	270
" 11	Chamber	12′ x15′6x10′	1,860	42′ W.	156
" 12	Bath room	7′9x 8′6x10′	650	18′ W.	75
" 13	Chamber	11′ x13′9x10′	1,520	54′ S. E. & W.	355
" 14	Hall	9′ x25′ x10′	2,200	24′ S.	120

NOTE.—Glass exposure of hall, first floor, estimated at one-half actual figures. Measurement into bay-window taken for dining room.

When estimating pipe sizes, area of flues and registers required, and the size of furnace necessary to properly handle the work, we have many rules to select from to guide us in the calculations. One authority states that the size of air pipes for the first floor rooms may be obtained by dividing the outside wall surface of each room by 3, the result giving the proper cross-sectional area in square inches of the desired air pipe. For the second floor take 5 as the divisor, and for the third floor 6, using always the pipe having an area next larger than that given by the computation. To illustrate, the size obtained by rule might be 74 square inches; therefore the next larger size of pipe would be 78 square inches, or one 10″ in diameter.

For rooms having an excessive amount of glass surface the area of the air pipe should be increased twenty-five per cent., and those having a northern and western exposure should have increased sizes of supply pipes.

This rule is based upon the fact that in the average type of building, the windows and outside doors (total glass surface) amount to practically one-sixth of the total exposed wall surface, and, further, it is estimated that four square feet of exposed wall surface is equivalent to one square foot of exposed glass surface.

While an application of the above rule leaves much to the good judgment of the furnace man, it is the beginning of a practical method for recognizing the difference in the cooling surfaces of a room, and it furnishes great improvement over the "hit-or-miss" methods so commonly used.

Those who consider the heat unit in estimating capacities, figure that one square foot of an ordinary brick wall will transmit or lose 16 heat units per hour, and that each square foot of glass surface will lose heat at the rate of 85 heat units per hour, these ratios being based on zero weather outside and an inside temperature of 70 degrees. Multiplying the total exposed wall surface by 16, the total glass surface by 85, and adding the products, will give the total hourly heat loss. For the first floor, multiply this result by 0.0094 to obtain the cross-sectional area in square inches of the warm air pipe. For the second floor the multiplier is 0.0047.

These multipliers are obtained as follows: The heat transmission which must be offset by the air supply is based on delivering the air into the rooms at 140 degrees in zero weather and allowing this air to cool to 70 degrees before it escapes. If the air supply were only cooled one degree to give up the amount of heat necessary there would be fifty-five times as many cubic feet of air required in an hour as there are heat units lost in transmission, since fifty-five cubic feet of air cooling one degree will only give up one heat unit. As, however, each cubic foot of air is to be cooled 70 degrees, the amount of air needed in an hour is obtained by taking 55/70ths of the number of heat units. As this is the number of cubic feet of air per hour, dividing by 60 will give the cubic feet per minute. In the first floor rooms the velocity which air will get in a furnace heating system, due to the height of the first floor registers above the hot zone of the furnace, is about 200 feet per minute. Dividing the total amount of air needed in a minute for heating the room by the velocity with which this air will flow, will give the number of square feet of area in the pipe needed to conduct the required amount of air. Multiplying this result by 144 gives the area of the pipe in square inches. Expressed numerically the operation is: Heat units $\times$ 55 $\times$ 144 $\div$ 70 $\div$ 60 $\div$ 200 $=$ heat units $\times$ 0.0094. If for second story rooms 400 feet velocity is allowed, as such velocity can be attained, the multiplier for the number of heat units becomes 0.0047.

The above are a few of the rules for determining capacities and pipe sizes, and we would say in this connection that any rule that properly takes into consideration the cooling surfaces of a building may be used with safety.

We like very much Mr. Prizer's rule for estimating the capacity of furnace required, and his method of determining the sizes of warm air pipes. Taking into consideration the cubic feet of air space, of exposed wall surface, and of exposed glass surface, Mr. Prizer reduces the cooling surface of each room, to an amount which he calls "Equivalent Cubic Feet."

The rule is as follows: Taking the actual cubic feet of space in a room as a basis, add 75 cubic feet for each square feet of exposed glass surface, and 8 cubic feet for each square foot of exposed wall surface. The provision for exposure is covered by adding ten per cent. to the glass and wall surface for a northern or western exposure, and deducting ten per cent. from the exposed glass and wall surface for a southern and eastern exposure. All outside doors, of course, are figured as glass surface, the same as with other rules. Should storm doors be provided, or double doors, those outside are then counted as exposed wall surface.

Adding together the totals thus obtained will give the Equivalent Cubic Feet of space to be warmed. The entire space in halls, provided the first floor hall opens into the second or possibly the third floor as well, is considered in figuring the size of pipe, etc., for the first floor hall. This rule, of course, is useful only when regarded in connection with tables giving the area of pipes and ducts for use with Equivalent Cubic Feet and with furnaces rated to take care of a certain amount of Equivalent Cubic Feet. However, it furnishes an exact basis on which to work and we consider it a very good and pronounced advance in the methods of estimating furnace work.

The illustrations included show the sizes of windows and doors and size of rooms, and we shall consider the same floor plans, giving data as to sizes of pipes, sizes and locations of registers, etc.

To determine the proper size of furnace for this work, we may use in our calculations any one of a number of rules. For instance, it is generally recognized that one square foot of grate area in a furnace will properly care for 5,000 cubic feet of space in the average dwelling. Using this rule in determining the size of furnace required, we figure the total cubic space to be warmed in the residence illustrated, as being a little more than 26,000 cubic feet, and dividing this amount by 5,000, show that a furnace having 5 1/5 square feet of grate is required, or one with an area of approximately 750 square inches. A circular grate, 31 inches in diameter, conforms to this requirement. This rule, we may say, is based upon the most extreme climatic conditions prevailing and for locations where the thermometer reaches from 10 to 20 degrees below zero.

A preferred rule and one which may be applied with safety is to determine the total amount of glass surface in the rooms to be heated and the total net exposed wall surface. It is correctly estimated that 1 square foot of grate in a furnace is capable of taking care of 300 square feet of glass surface or its

equivalent, 4 square feet of exposed wall surface being considered the equivalent of 1 square foot of glass.

Considering now the residence illustrated, we find a total glass surface of a little more than 600 square feet. The total exposed wall surface is 3,130 square feet, and after deducting the glass area from this total amount, we have a net exposed wall surface of about 2,500 square feet. Reducing this net amount to its equivalent in glass surface by dividing by 4, on the basis mentioned, gives a product of 630 square feet of equivalent glass, which, added to the actual glass surface, 690 square feet, makes the total 1,239 square feet of glass.

Now, applying the rule just given, we divide this sum by 300, and learn from the result that a furnace having a little more than 4 square feet of grate surface would probably do the work. Other formulas used in like manner show that a furnace with from 4 to 5½ square feet of grate surface would be the size necessary for this requirement.

No person without experience is capable of applying any one of the rules with precision. The judgment of an experienced man increases the value of all rules, hence by using them in accordance with what his better knowledge of the conditions surrounding the work teaches him, the result will be more in keeping with that obtained by practical experience. In our opinion for this work a furnace should be placed which has a grate area of about 700 square inches, which would mean a 30-inch grate.

When working out the estimate for the sizes of the warm air pipes in the cellar, the same discrepancy is found when applying miscellaneous rules as is noted when determining the size of the furnace. Good judgment based upon practical experience demands that no warm air leader pipe in the basement should be smaller than 7 inches in diameter, no matter what the size of the connection may be.

Given herewith is a schedule showing the sizes of warm air cellar pipes, of vertical flues, and of registers required for this residence, and in this connection attention should be called to the fact that every register and vertical flue is supplied by a separate warm air pipe, with the exception of the library and the guest chamber above.

A baseboard register is planned for the library, while a combination vertical flue, supplied by a 13-inch warm air leader, serves the library and guest room over it. The character of this flue and the position of the register are indicated in Fig. 27.

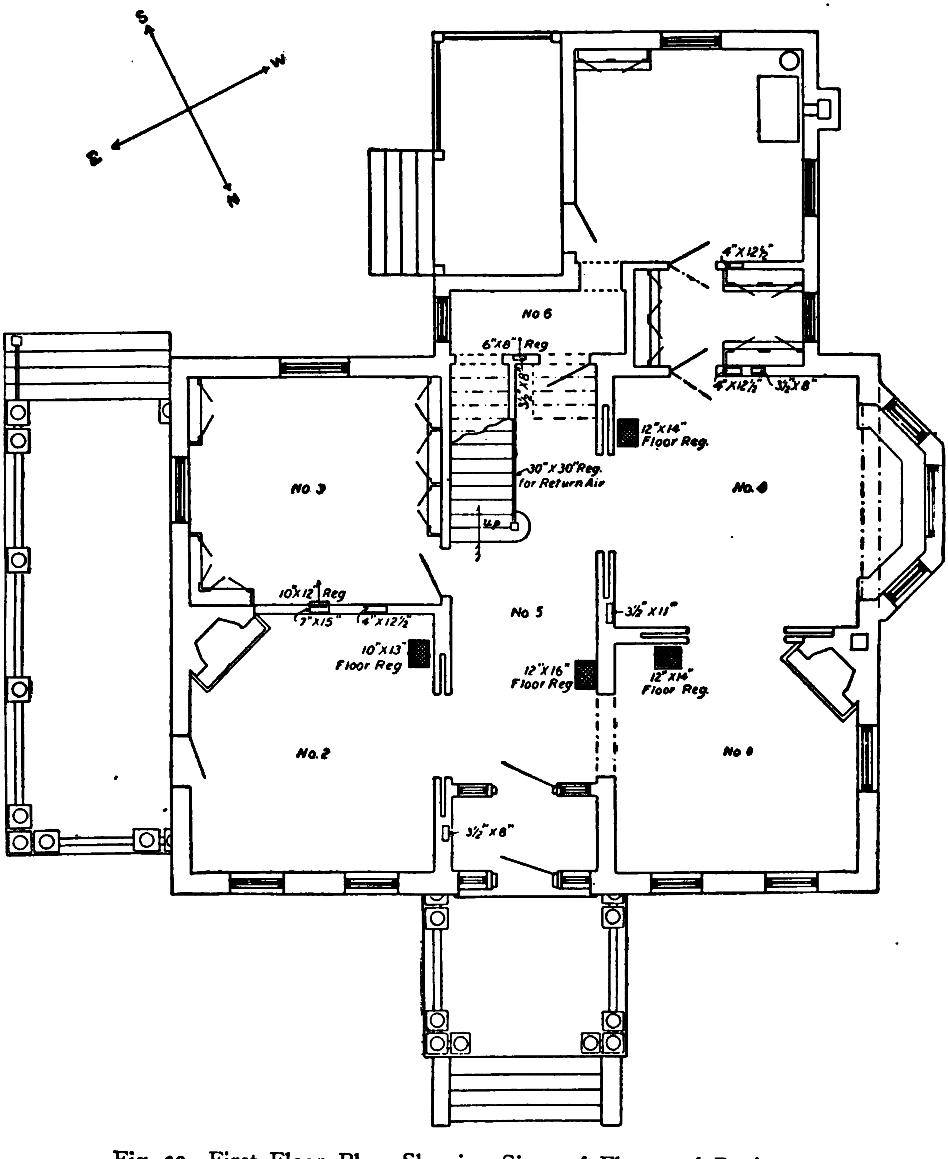


Fig. 32—First Floor Plan, Showing Sizes of Flues and Registers.

Fig. 32 shows a plan of the first and Fig. 33 a plan of the second floor. The sizes of all registers and hot air flues are given, together with their locations.

The fireplaces in the parlor and living room prove to be natural ventilators for these rooms.

Room.	Size of warm air cellar pipe.	Size of vertical flue.	Size of register.
Parlor	11	6¾x14	12x14
Living Room	10½	6 x15	10x13
Library	13	7 x15	10x12
Dining Room	11	6¾x14	12x14
Reception Hall	11	6¾x14	12x16
Rear Entrance	7	3½x 8	6x 8
Den	7½	3½x11	8x10
Alcove	7	3½x 8	6x 8
Chamber	8	4 x12½	10x10
Guest Room	(See Library)	3½x11	8x10
Chamber	8	4 x12½	10x10
Bath Room	7	3½x 8	6x 8
Chamber	7½	4 x12½	10x10
Hall	(Included with first floor)		

Arrangement is made to recirculate the inside air from the lower floor. A 30″ × 30″ circulating register is set in the paneling of the main stairway, this register opening into a chamber 24″ × 36″, located under the stairs. Connecting with this chamber is a 16″× 30″ duct, which is carried along the ceiling of the basement to that certain point, where a vertical drop to the floor of the basement can be made without interfering with the passage-way or piping. At such particular point the drop is made and the duct then connected into the cold air pit of the furnace at the side opposite to that from which the cold outside air enters the pot. This duct is provided with a damper.

Fig. 34 shows a plan of the basement and illustrates the manner of locating the furnace and of installing the piping. The sizes of all leaders are marked, and also the location and size of the circulating duct, the cold air chamber, the cold air duct, and the smoke connection.

The cold air or filtering chamber is 3′ × 4′ 6″ in size, and is provided with baffles on which cheese cloth is stretched sufficient to cover about two- thirds of each bafflle, all of which are removable for cleaning. The sash of the window is hinged at the top and a chain connecting to it is run to a convenient point outside of the cold air chamber, by means of which the supply of cold

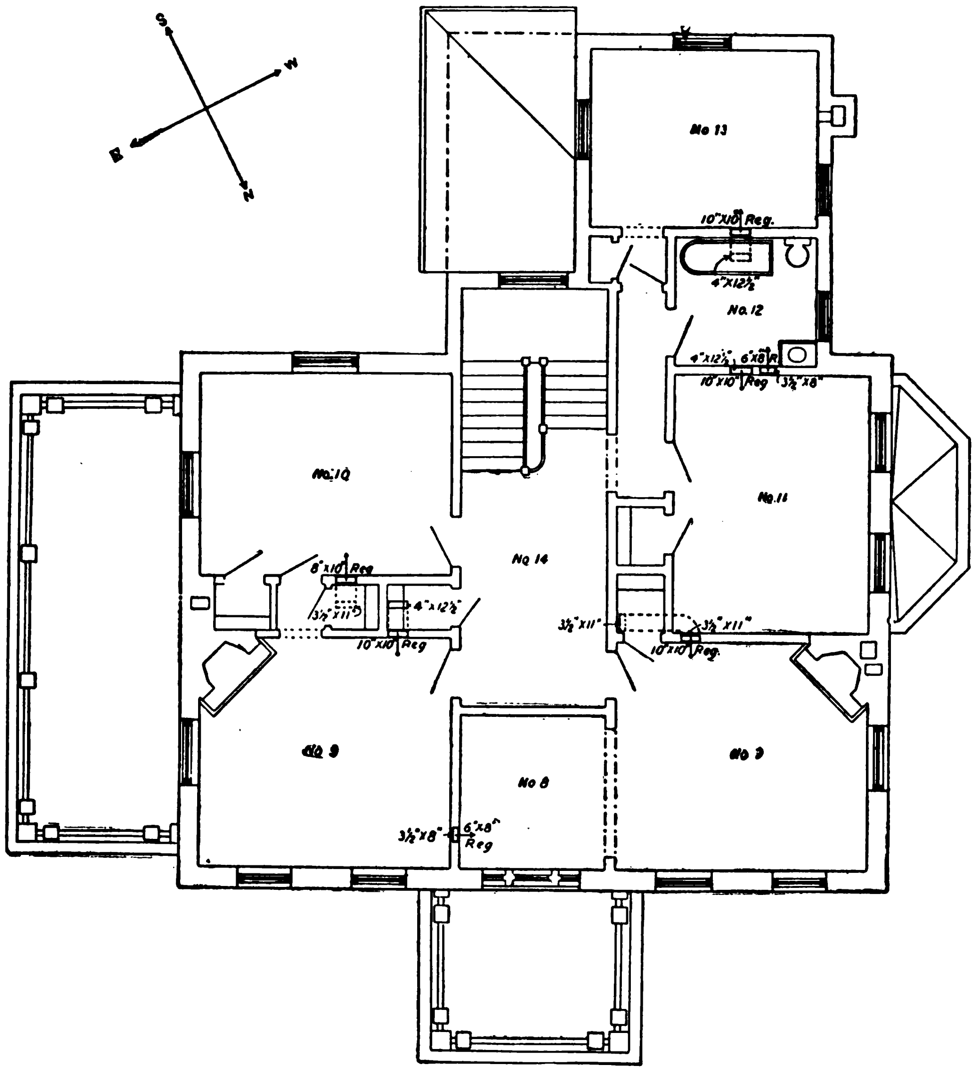


Fig. 33—Second Floor Plan, Showing Sizes of Flues and Registers.

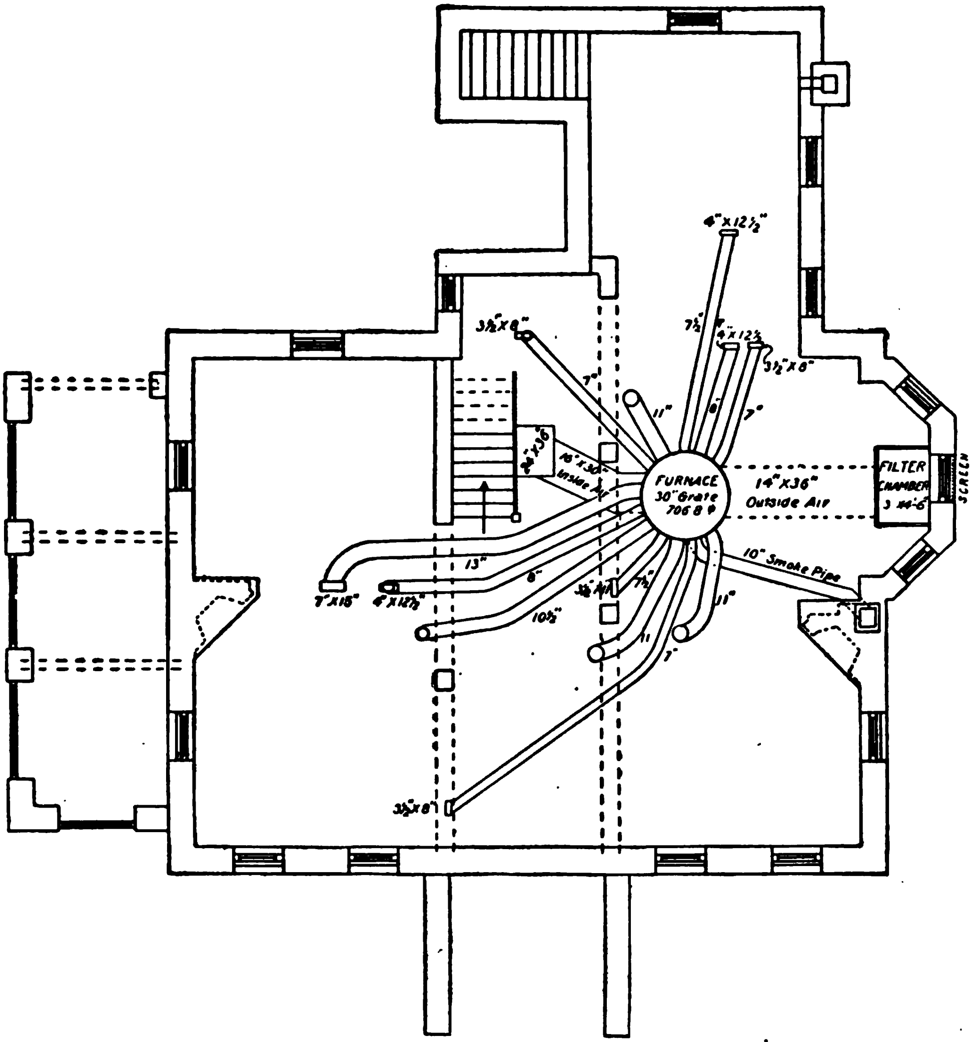


Fig. 34—Basement Plan, Showing Method of Locating Furnace and Piping

air is controlled. Fig. 35 shows a sectional view of this chamber with the cold air duct leading from it. This duct is 14" × 36" in size, and built of cement with an arched cement top.

The installation of an apparatus as here described will cost double the amount usually paid for the cheap work ordinarily placed. The owner, however, will have the desired satisfaction of being able to thoroughly warm the house, regardless of the condition of the weather or the direction of the wind.

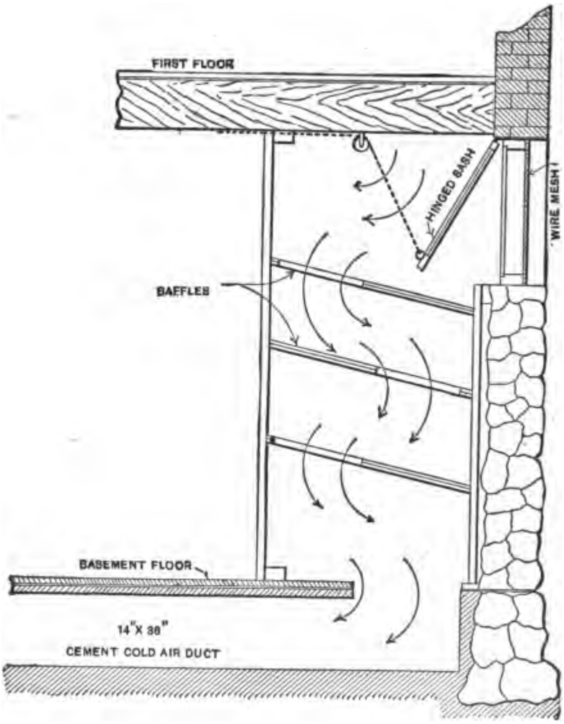


Fig. 35—Sectional View of Filtering Chamber.

A few general directions for the installation in question should be given, as follows:

Place dampers in all leaders, except that feeding the reception hall.

Connect all dampers with chains running to a switchboard or chain plate, located in rear entrance of first floor, or at some other point equally convenient.

Thoroughly cover all basement piping with heavy asbestos paper.

Make use of anti-friction connections in joining leaders to vertical air flues. This style costs more, but is worth more than it costs.

Give a good pitch to all leaders, as air will not travel through a horizontal pipe without friction.

Many other minor directions might be included. However, the furnace man accustomed to superior work will recognize in the data supplied all that is required to cover a good job.

CHAPTER V

TRUNK LINE AND FAN-BLAST HOT AIR HEATING

Every one identified with furnace heating understands, we believe, that more friction prevails in conveying air or water through several small pipes than when combining the same volume and carrying it through one or more larger pipes. With plenty of headroom in the basement the pipes may be made round; under other conditions they should be rectangular in shape.

In starting to lay out a trunk line job the designer of the system should keep in mind the following rules and plan accordingly:

(a) A single pipe feeding two or more smaller ones must have an area equal to the combined area of all pipes supplied by it. See Fig. 36.

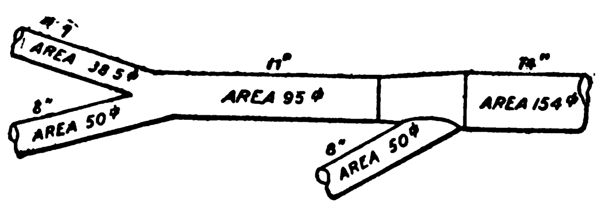


Fig. 36—Plan of Trunk Line.

(b) In order to eliminate the friction due to choking and the presence of pockets, the top line of all piping should be straight; therefore any "drawing in" or reduction of the piping must be made at the sides and bottom. Fig. 37 illustrates this condition.

(c) A certain pitch of the piping having been established it should be continued from the furnace to the last register or riser supplied.

(d) Do not make reductions too quickly. Often a single register supplied will not change the size of the main service pipe, and such connections, when near the furnace, should be taken

from the side of the trunk line at the bottom line of the pipe, as illustrated by Fig. 38.

(e) Branches, if of considerable length, may be run from the top of the trunk line, and where the construction of the building permits, the branch may be carried between joists as indicated by Fig. 39.

These include the most essential points considered in laying out the piping of a trunk line system, and although practically

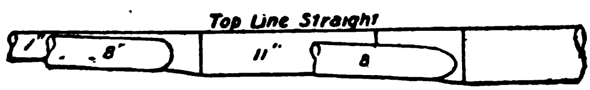


Fig. 37—Elevation of Trunk Line.

every job presents new difficulties necessary to meet and overcome, the rules herein submitted form a safe starting point in developing the system of piping.

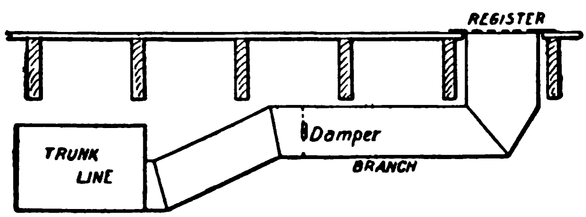


Fig. 39—Connection Carried Between Joists.

Select a furnace of generous size for the work, one having an area for the passage of air of from 40 to 50 per cent. greater than the area of the trunk lines. Work of this character is not cheap and if the furnace man is considering a low or even moderate priced installation he must not figure on a trunk line system. But if the best is to be selected with a view to procuring durability, or length of service without repairs, as well as comfort and satisfaction from the use of the apparatus, such a system properly installed will suitably answer every requirement. In this age of specializing, trunk line heating may be properly regarded as a specialty requiring the attention of specialists, and of your best workmen none are too skillful for such work.

When necessary to change direction with a trunk line, do not make an abrupt turn at right angles; rather turn with a long sweep in order that the air can move in the new direction without any considerable friction.

It is usually the case that two or three registers or risers are supplied by the trunk line at or near to the end of it and that

two or three branches lead from it between the furnace and the extreme end. With round piping these branches should be taken from the tapering sleeve, reducing the size of the trunk line. When rectangular piping is used (and this style is preferable), take the branches from the side of the pipe at the bottom, as the air in passing through hugs the top, seeking the first outlet.

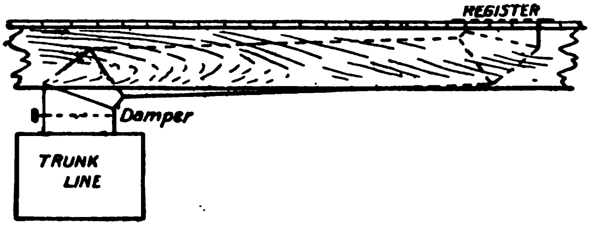


Fig. 38—Connection Taken from Side of Trunk Line.

Fig. 40 will show clearly the reason for this and illustrates how and why the connection of a branch does not interfere with the hottest air traveling along the upper side of the trunk line to its extreme end.

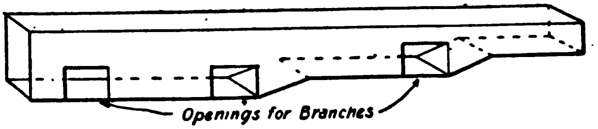


Fig. 40—Rectangular Trunk Line, Showing Out for Branches and Method of Reducing Area.

Secure the trunk lines firmly in place by straps of light band iron screwed or nailed to joists. A quarter turn in each vertical upright will afford a good appearance to the hanger and permit it to fit snugly against the joist. Fig. 41 gives an outline of the method for its use.

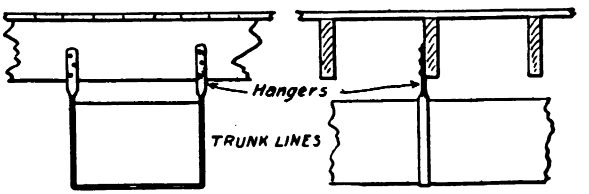


Fig. 41—Method of Supporting Trunk Line.

The furnace man who wishes to construct a job that will surely please and delight his customer, as well as prove a source of great satisfaction to himself, will do well to try out this system

on the next installation of good size, when we predict he will become a convert to the principle of moving air in large volumes and ever after remain a stanch advocate of the idea. Air cools quickly in small pipes, and consequently must be heated to a higher temperature than when otherwise carried.

Suppose a furnace job erected by the regular method requires two 10", two 11", three 8" and one 12" pipes. Their combined area would be 600 sq. in. and the total circumference approximately 254.5 inches. If a single trunk line could be substituted a 28" pipe with an area of 615.7 sq. in. would be needed. The circumference of a 28" pipe is 88 inches, and therefore the cooling surface in the small piping is nearly three times that in the one 28" trunk line.

The brainy successful furnace man, ever on the lookout for ideas and methods that will enable him to do better work, finds much food for thought and study when considering the trunk line system of furnace piping. Those who never attempt to rise above the old tried out, and often worn out, methods of doing a certain line of work never advance farther than to obtain possibly the name and reputation of good all around workmen.

While not believing in the right of the furnace man to experiment at the expense of a customer, there are certain theories, methods and suggestions which must necessarily be tried out in actual practice if we are to progress in our business, and there is no house owner but wants the best character of heating apparatus if obtainable at a price within his means. This can signify but one thing to the furnace man: He must (as he should) accept the full responsibility for his work, guaranteeing to make any changes necessary to the complete fulfillment of his agreement with the owner.

The same care in the proper installation of the furnace, size of same, and method of introducing fresh air and exhausting the foul, is as essential for the trunk line system as for the regular system of piping, to insure a successful working job.

A method of running furnace pipes, which has been styled the "trunk line system," finds much favor among furnace men in certain localities. However, in other parts of the country it is little known or adopted, probably because a considerable amount of study and care need be exercised in its installation if good results are to be obtained from its use. The system covers a simple positive method of conveying air to the various stacks and registers of a furnace heating system.

When planning for the installation of the trunk line system the sizes of furnace, stacks, registers and cold air supply remain the same as for the regular method, the only difference between the two systems lying in the manner of running the basement pipes.

Fan Blast Hot Air Heating

In discussing the subject of warm air heating and the possibility of apparatus for such purpose, we have thus far considered only those systems which circulate the air by reason of the difference in the specific gravity or weight of the warmed or expanded air, and that of the denser cold air admitted through the cold air duct.

In localities where electric current is available for power, an electrically operated and controlled fan may be employed to good advantage in connection with the furnace. It is possible with the use of a fan as an auxiliary to the heating apparatus to change the air frequently and positively, no matter what may be the direction or velocity of the wind or the location (as to exposure) of the rooms to be warmed.

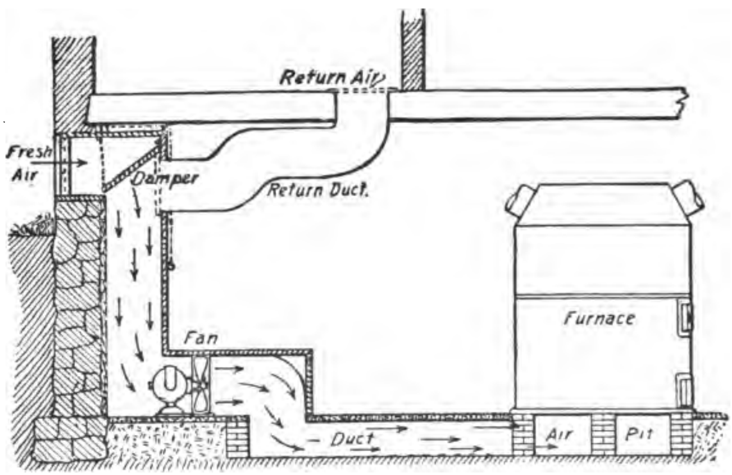


Fig. 42—Diagram of Arrangement for Exhaust System.

A system of this kind would be called a "mechanical system," "fan-blast system" or a "warm air fan system," and is particularly adaptable when employed to ventilate buildings in which many people congregate, such as a church, school or public hall, and also for large residences of the modern type.

Some of the larger residences of this class could not be warmed with an ordinary hot air system except by the installation of two or more furnaces, each located in different sections of the building, while with a fan-blast hot air apparatus the furnaces (if more than one be necessary) may be located at some central and convenient point in the basement, and the trunk line

method of piping, as described in a recent article, used to convey the heated air to the several risers or stacks. Warm air ducts when few in number not only present a neat appearance, but are greatly to be desired when the efficiency of the installation is to be considered.

Should a fan be employed in connection with a heating and ventilating system, either one of two methods may be adopted. They are known as the exhaust and the plenum methods, and are separate and distinct from each other in the manner of installation and operation. The exhaust method, which is illustrated by Fig. 42, is installed as follows:

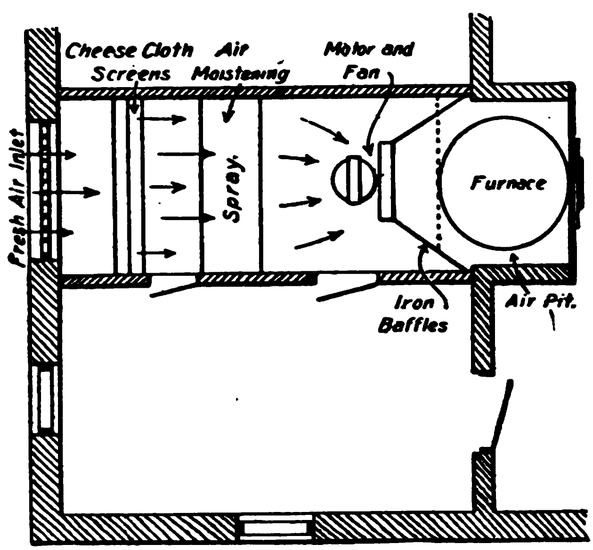


Fig. 43—Arrangement for Plenum System Shown in Plan.

The furnace is located in the usual manner and place. The cold air is admitted to the furnace in the usual manner through a cold air duct connecting with a pit under the furnace, and is drawn upward over the heated surfaces of the furnace, warmed, and conveyed to the several rooms through air ducts and registers. The foul or impure air is exhausted from each room through a foul air register connecting with a foul air duct. These ducts extend to the attic of the building, where an exhaust fan of sufficient size is located which propels or drives this air from the building through an opening in the wall or through roof ventilators. In other words, the fan creates a vacuum which pulls the pure warm air through the building and exhausts it to

the atmosphere, after the heat conveyed by it has cooled and the air has become foul owing to the respiration of the occupants of the building, or by other sources of contamination. The suction produced by the fan causes an infiltration of air through crevices around doors and windows, the amount varying in volume according to the size and speed of the fan.

The plenum method, as illustrated by Fig. 43 is the system more generally used in connection with furnace heating. In arranging the apparatus the outside air is admitted through a wire or grill screened opening in the outside wall into a chamber within the basement of the building. Here it may be filtered to remove dust and dirt and may also be moistened if such a condition is desired.

The air then passes through a duct to the fan, which propels it forward through the furnace and warm air ducts into the various rooms to be warmed and ventilated.

The foul air is exhausted through registers into ducts or flues which extend upward through the building to a point well above the roof.

With this system in operation the air leakage around outside doors and windows is outward, as the fan drives the air through the system and into the rooms under a slight, though constant, pressure and a certain definite air change may be figured and secured whatever may be the condition of the weather.

The ventilation of a building is now considered by both architect and owner to be as essential as the heating system, and a modern residence is not considered complete unless it is well ventilated. All persons versed on the subject of ventilation, and who are competent to advise, say that there can be no ventilation when a building is warmed by direct steam or hot water or by a furnace without a generous admission of fresh air to the building, and the mission of the furnace has not been fulfilled until this fresh air feature has been provided.

We have met with the argument that it is expensive to burn the fuel necessary to warm so large a volume of fresh air, a perfectly true statement. To this we may answer—and likewise the services of a physician are costly, and which is the cheaper in the end: a coal bill based upon the warming of sufficient fresh air to insure healthfulness, cheerfulness and comfort, or a coal bill based upon no ventilation or recirculated air, with the attendant consequences of ill health, doctors' fees and loss of time from business, to say nothing of the discomfort attending such experiences.

When a residence is but sparsely occupied (as the majority

of all residences are) an air change three times per hour will provide all of the ventilation necessary, and this rate of air change may be obtained with very little increased expenditure for fuel—provided the apparatus is properly arranged—and it may be increased to five or six changes per hour at times when the rooms are to accommodate an exceptional number of people, as at the time of a social gathering.

With a fan furnace system installed, an air change of five times per hour may be easily obtained without an excessive expense for fuel.

When the building is unoccupied, or but sparsely so, it is not necessary to use the fan, and the expense of its operation may be saved. This is particularly true when a system of this character is installed to warm and ventilate a school building. Certainly it is not necessary to operate the fan when the rooms are unoccupied, and a school building is occupied only six or seven hours a day, never more than eight hours.

All ventilating ducts should be provided with close fitting dampers located above the outlet register. Within a short time after school is dismissed the fan should stop running and these dampers should be closed, and remain closed until possibly eight o'clock the following morning when the attendant should open them and put the fan in operation.

At periods when the atmosphere is heavy or depressing or on occasions when the building is to be generally well occupied, the turning of a switch sets the fan in motion and the effect is at once apparent in the condition of the atmosphere.

Experience obtained in testing the movement of air by a fan has demonstrated that it is better and more economical to use a large fan run at low speed than it is to move the same volume of air with a smaller fan run at high speed. The areas of all ducts and stacks for both fresh and foul air should be carefully figured, and the installation be made in such a manner as to avoid all of the friction possible in moving the air. For this purpose there is an abundance of definite and dependable data to be had.

The warm fresh air should enter the room above the breathing line; therefore, the inlet registers should be located about seven and one-half or eight feet from the floor.

The outlet or ventilating registers should be placed near the floor line, preferably just above the floor or the base board, and the location of both fresh air and foul air flues and registers should be in the inside walls of all rooms.

Fan Blast Heating with Trunk Line Piping

The possibilities of good furnace work are shown by the installation of the hot air furnace in the residence illustrated herewith, which also affords a good example of the fan blast system used in connection with trunk line piping.

This residence is a brick structure containing nine rooms with bath and the usual halls, closets, etc., and as the photograph, Fig. 44 shows, the building stands alone and is exposed on all four sides to the elements. The building is not ventilated—that is, there is no provision made for exhausting the foul air through

Fig. 44—Residence in Which the Heating System was Installed.

ventilating ducts or otherwise except by means of the fireplace in the library. The heating apparatus is installed in quite the same manner as has been described on pages 57 to 60.

The fan forces the cold air under a slight and constant pressure through the furnace, and thence into the various rooms to be warmed, thus giving positive service to each room. The employment of extra large ducts admits of a larger volume of air supply than would be possible with the regular style and size of basement piping. The schedule of sizes and exposures of the various rooms is as follows:

FIRST FLOOR.

Room.	Wide, ft.	Long, ft.	High, ft.	Cu. ft.	Wall Surface, Sq. ft.	Glass Surface, Sq. ft.
Living Room	14	16	10	2,240	300	51
Dining Room	14	16	10	2,240	300	90
Library	12	14.6	10	1,740	270	51
Kitchen	14	14.6	10	2,030	220	60

SECOND FLOOR.

Room.	Wide, ft.	Long, ft.	High, ft.	Cu. ft.	Wall Surface, Sq. ft.	Glass Surface, Sq. ft.
Hall—inc. 2nd floor....	8	22	10	3,344	80	54
Bed Room No. 1......	13.6	15.6	9	1,881	261	42
Sewing Room	8.6	10	9	765	72	24
Bed Room No. 2......	13	14.6	9	1,692	247	42
Bed Room No. 3......	13	14.6	9	1,692	216	42
Bath Room	5.6	11	9	540	50	15
Bed Room No. 4......	10	14	9	1,260	216	54
Totals....................................				19,424	2,232	525

The size of furnace required may be determined by the rule that one square foot of grate should be provided for each 5,000 cu. ft. of space to be warmed.

The cubical contents of the various rooms as shown by schedule is nearly 20,000 cu. ft.; therefore, 20,000 ÷ 5,000 = 4; this number indicates that a furnace having 4 sq. ft. of grate should be selected.

Another rule, and one we consider more accurate, is that 1 sq. ft. of grate in a furnace of good construction is capable of taking care of 300 sq, ft. of glass or its equivalent in exposed wall surface, 4 sq. ft. of exposed wall being considered equal to 1 sq. ft. of glass.

Having a total exposed wall surface (gross) of 2,232 sq. ft., and a total glass surface (outside doors considered as glass), of 525 sq. ft., we proceed as follows: 2,232 ÷ 4 = 558 equivalent glass surface; 558 + 525 = 1,083 ÷ 300 = 3.6 sq, ft. requiring a furnace having a grate 3.6 sq. ft. in area or about 26 inches in diameter. However, as we desire to handle a larger volume of air than would be required with the regular or old style system, we deem it advisable to increase the grate area practically 20 per cent., and therefore estimate to use a furnace having a grate area of 4.3 sq. ft. or a grate 28 inches in diameter.

Figs. 45 and 46 show the first and second floor plans of the residence on which the sizes of all registers and risers are noted, and their location shown. The compactness of the system may be determined at a glance.

The sizes of both risers and registers are larger than would regularly be employed.

The basement plan of the building is illustrated by Fig. 47, and it will be seen that the piping takes up but little space, and being rectangular in form interferes but little with head room in the basement.

The duct work is constructed entirely of galvanized iron. The risers and register boxes are made of tin. Each branch duct has its independent damper for regulating the air supply to each room, and the casement opening through which the cold air is

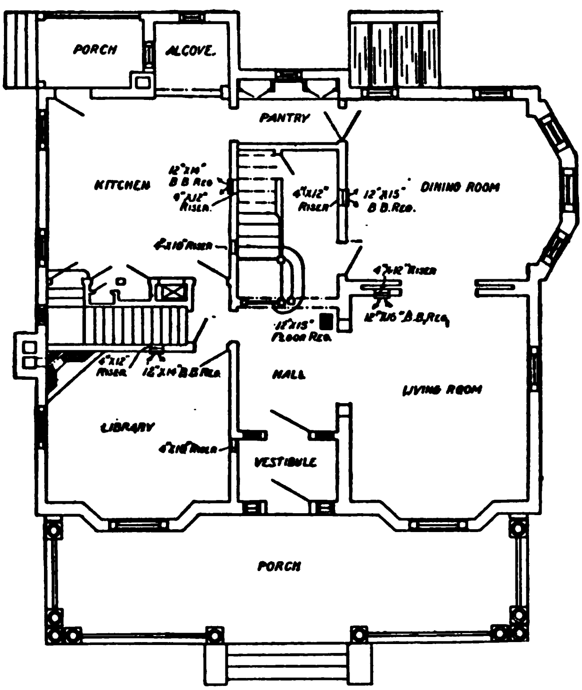


Fig. 45—Plan of First Floor.

admitted to the cold air chamber is covered with a window, the sash of which is hinged at the top and which, used as a damper, may be opened or closed to regulate the amount of air delivered to the fan. These dampers are not shown on the plan.

The value of the positiveness of such a system as that illustrated can scarcely be realized. It must be admitted by practical furnace men that a building can seldom be found where the air is properly and, we might say, satisfactorily supplied and distributed

by a furnace. Such installations are the exception rather than the rule.

We know that we challenge argument by this statement, yet we believe every fair minded practical furnace man will agree with us.

It seems a pity that there is but one fireplace in the residence illustrated. Fireplaces are natural ventilating flues, and a fireplace in the living room and a ventilating flue in the wall of

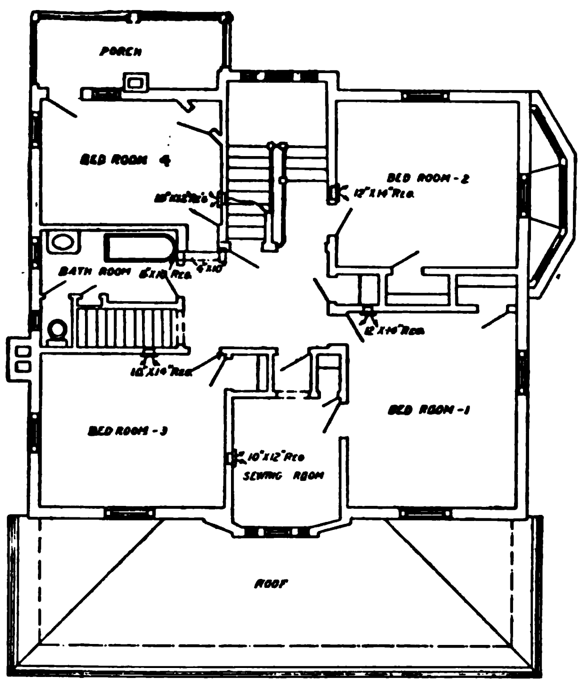


Fig. 46—Plan of Second Floor.

the dining room and possibly the hall would make the system an ideal one for both heating and ventilating in the winter, or for cooling and ventilating in the summer.

The fan is a 24" direct connected electrically driven fan, which, when used, is run at low speed, is noiseless, and requires very little power to operate it. The wiring is connected to a switch located in the dining room, from which point the fan is put in operation or stopped.

A chain from the window in the cold air box also runs to the

dining room, and the window used as a damper may be opened wholly or in part without entering the basement.

By enlarging the cold air box sufficiently, filters for removing dust or impurities from the air might be installed, and if desired an air moistening apparatus might also be employed.

A marked improvement in the system illustrated would be the addition of two large registers—one in the side panel of the staircase and one in the inner wall of the living room, connecting

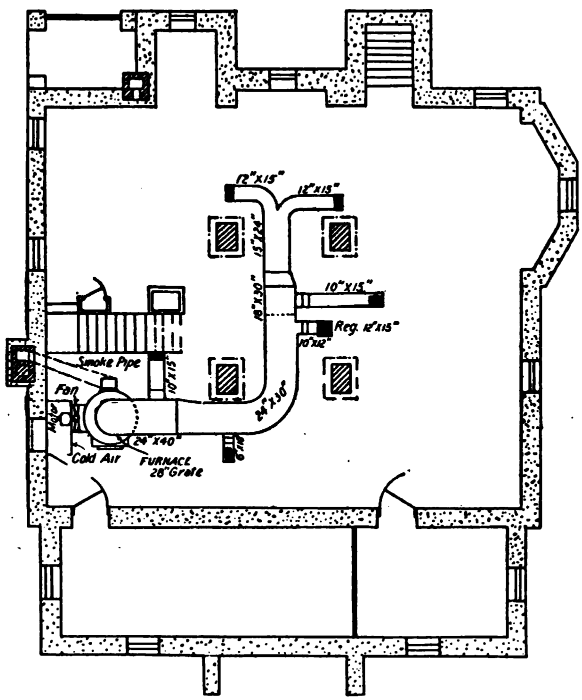


Fig. 47—Plan of Basement.

by means of a duct directly with the air pit of the furnace on the side opposite to that where the fresh air is admitted.

These would be called rotating air registers, and would be used for rotating or recirculating the air within the building at periods when it was not sufficiently occupied to require the fresh air service.

Of course this duct would be properly dampered with a close fitting damper to be closed when the fan is in operation or when the fresh air service is in use.

CHAPTER VI

ESTIMATING FURNACE WORK

In estimating a job of furnace heating, having determined the sizes of furnace, registers and piping, we advise the grouping of items figured for the work. For instance, under the head of "Furnace" we would include the following:

Cost of furnace, plus 10 per cent., and freight and cartage. Foundation, casing, cold air duct, cement and asbestos.

Under the item of "Piping" include the number of feet of each size of leader or basement pipe, the number of feet of each size of riser; then, in turn, collars, dampers, elbows, boots, register boxes and any extra fittings.

Under "Ventilation" include the number of feet and size of circulating pipes, floor register boxes and any special dampers.

Under "Registers" include the number and size of all warm air registers, faces and borders, the number and size of all ventilating registers, faces and borders.

Under the item of "Labor" should be estimated the actual labor of installing the apparatus, masonary and carpenter work (if needed) and labor expenses, such as car fares, board, etc. In estimating the labor on an ordinary house or residence job of furnace heating, it is well to regard the digging of the cold air pit and the building of the brick foundation as constituting half a day's labor; and later, that the setting of the furnace, cementing, casing, smoke connection, cutting for the clean-out doors and leaders constitute another half a day, making a total of one day, not usually figured. Estimate from one-half day to one day for cutting holes in floors and walls, one-half day for running risers and one day for ventilating work, setting registers and finishing. This totals three days' work for two men, which should be sufficient to install the job complete.

Under "Miscellaneous" estimate smoke connection and damper and all incidental expenses not otherwise charged, and finally add the item of "Profit," remembering that it costs 10 per cent. to do

business, and if you add but 10 per cent. to your figures you will lose money on the job, besides assuming the responsibility of the work. You are entitled to a profit upon your labor and also upon the expenses paid in shouldering the responsibility of the contract.

Do we hear somebody ask why 10 per cent. is added to cost of furnace under this item? If so, we would answer that it is to cover time spent in estimating and closing the job, and this rate of percentage is but a small margin to pay for this work.

Fig. 48—View of House Used as Basis of Estimate.

We advise the use of a small loose-leaf estimating book, say, 5x7 inches in size, indexed, in which may be marked or pasted such tables and data as will facilitate quick figuring, lists of material with net costs figured out, etc. Mistakes in estimating are due usually to haste when compelled to compile an estimate hurriedly, and a book with prices, etc., figured out at leisure, the figures checked to insure accuracy, will prove invaluable to the furnace man.

There are many rules for rapid estimating, some of which are excellent when used with good judgment. Those which

one man may study out and apply with ease may prove hard to adapt by another man, and we had rather employ our own data, collected and classified in an estimating book, than to attempt to use or apply many of the rules given by various authorities.

The photograph shown herewith is that of what would be termed an eleven-room house. It is of frame construction and well built, the outside wall being protected by the use of heavy building paper, applied over well covered siding, after which the

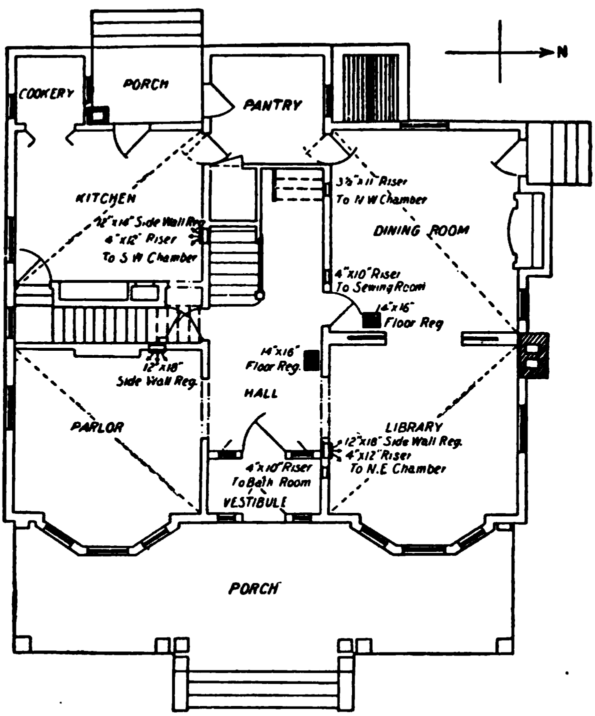


Fig. 49—Plan of First Floor.

walls are covered with clapboards and shingles. The building has slightly more than the ordinary amount of glass exposure and, as it stands alone, without the protection of adjacent structures, it may be considered a difficult house to warm.

The building faces nearly due east, the chimney noticed on the photograph being on the north side.

When considering a furnace job for a dwelling we have frequently heard the remark passed that the building could not be heated satisfactorily with hot air, owing to the fact that it was

unprotected from the influence of wintry winds—a statement, however, which cannot be borne out by results, provided the heater and piping can be properly installed. In the case where such a statement proves true, it may usually be traced to the fact that the building is poorly constructed and the apparatus inadequate, owing to incorrect estimating or to the apparatus being improperly installed.

Fig. 49 is a plan of the first floor, containing five principal rooms, parlor, library, dining room, kitchen and reception hall,

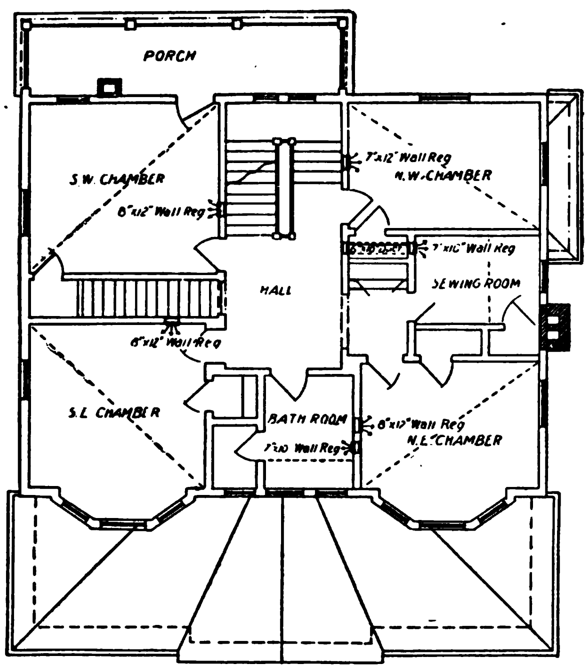


Fig. 50—Plan of Second Floor.

together with a vestibule, pantry and a cookery in which the range is located.

Fig. 50 shows the second floor, with four bedrooms, a sewing room and bath room.

The necessary information as to sizes and exposures of rooms should be tabulated in an estimate book kept for the purpose, and for this building the data would appear as follows:

TABLE OF EXPOSURE.

First Floor.	Size.	Cubic Contents.	Glass.	Exposed Wall.
Parlor	15 x 15 x 10	2,250	72	228
Library	15 x 15 x 10	2,250	72	198
Dining Room	16 x 16 x 10	2,560	64	256
Kitchen	12 x 15 x 10	1,800	64	100
Reception Hall	9 x 22 x 10	....	..	...
Second Floor Hall	9 x 21 x 10	3,870	81	...
Second Floor.				
S. E. Chamber	14 x 15 x 9	1,890	72	189
N. E. Chamber	14 x 12 x 9	1,512	72	162
Sewing Room	7 x 9′9″ x 9	621	18	45
N. W. Chamber	10 x 15 x 9	1,350	36	189
S. W. Chamber	13 x 15 x 9	1,755	64	188
Bath Room	7 x 9 x 9	567	..	...
Toilet	3′6″ x 5 x 9	155	46	...

With this data in hand, properly scheduled, the person estimating may use any one of the various rules given from time to time in these articles for determining the size of furnace, pipes, registers and fixtures. These we do not deem it necessary to repeat, and instead will follow with a tabulated statement of sizes of pipes and registers as they should appear on the record for estimating.

TABLE OF SIZES.

Room.	Diameter of cellar pipe.	Size of vertical flue.	Size of register.	Notes.
Parlor	13 in.	7 x 22	12 x 18	Side wall reg.
Library	13 in.	7 x 22	12 x 18	" " "
Dining Room	12 in.	Floor register	14 x 16	Floor "
Kitchen	12 in.	7 x 16	12 x 14	Side wall reg.
Reception Hall	12 in.	Floor register	14 x 16	Floor "
S. E. Chamber	(See Parlor)	4″ x 12″	8″ x 12″	Wall reg.
N. E. Chamber	(See Library)	4″ x 12″	8″ x 12″	" "
Sewing Room	8 in.	4″ x 10″	7″ x 10″	" "
N. W. Chamber	9 in.	3½″ x 11″	7″ x 12″	" "
S. W. Chamber	(See Kitchen)	4″ x 12″	8″ x 12″	" "
Bath and Toilet	8 in.	4″ x 10″	7″ x 10″	" "

Total area of basement pipes, 768 sq. in.

When requested to furnish an estimate of the cost of a furnace installation, the heating contractor should first measure the building, that is, obtain the sizes of the rooms to be warmed, the square feet of glass surface, and the square feet of exposed wall surface, making note at the same time of any extraordinary outside exposure.

The next step is to inspect the chimney flue to which the furnace will be attached, making a careful examination of its area, height and location.

Then observe and mark the points of the compass, the direc-

tion the building faces, and, as far as possible, study the character of its construction. The location of the chimney and the points of the compass will determine where the furnace must be set in the basement.

Next examine the basement of the building to ascertain if the furnace can be set in the proper location to do the best work and note also, at the time, if there is any obstruction, due to building construction, which would interfere with the proper alignment of the piping. It is preferable that the furnace occupies a position well to the north and west sides of the house. Note further if proper provision can be made for the cold air supply, which should preferably be taken from the north or west side.

It is advisable now to make a small sketch of each floor (not necessarily drawn to a scale) and to locate on it the permanent fixtures in each room, such as the tub, closet and washstand in the bath room, the sink, cupboards and other fixtures in the kitchen, etc.

The registers for hot air heat should be located in or along the inner walls of each room, and in this connection note on Figs. 49 and 50 the dotted lines drawn diagonally across the rooms. The registers should be placed at some point on the inner side of the room, as determined by the dotted lines.

The furnace man should similarly divide the rooms on his sketch, and then examine each to see at what point the register can be placed without interfering with the location of furniture and fixtures.

Having obtained the necessary data and information, as noted above, the contractor may now return to his place of business to figure out his bid for the work. The details of the job should now be tabulated as given above, the proper sizes of all pipes, registers and fixtures and of the furnace being arrived at by the use of some good rule, taking into account the exposure, glass and outside wall surfaces of the various rooms to be warmed.

To facilitate the figuring of costs, the heating contractor should have convenient lists, giving net prices of registers, register boxes, various sizes of leaders, dampers, elbows, boots, single and double heads, etc., and as a further help, an estimate blank, prepared for the purpose, should be used to show the various items necessary for the job.

Fig. 51 shows a basement plan of the residence used for illustration. The location and size of furnace, the size and method of running leaders, and the size and location of cold air chamber and cold air duct are given on the plan. The details and forms to be observed and followed in preparing a clear and concise

tabulated description of the material aand labor necessary to do the work we shall describe and discuss herein.

It is not essential, however, that the furnace man adopt the particular forms outlined in these articles. An estimate blank which will give, in order, all the information necessary to enable the estimator to figure accurately on the material required, together with the size and cost thereof, will prove as valuable and suitable as the form we submit for this purpose.

A table showing the sizes and exposures of the rooms to be warmed is first necessary, followed by one giving sizes of flues, registers and cellar pipes. With this information in hand, next

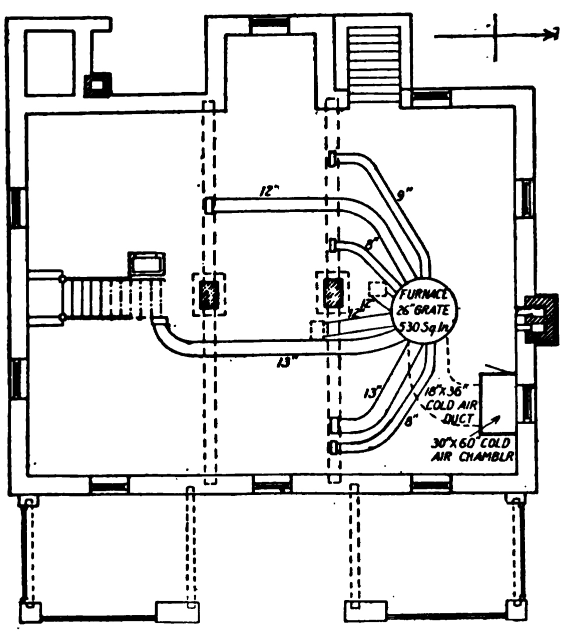


Fig. 51—Plan of Basement.

comes the selection of the proper size of furnace, and by "proper" size we mean that size that will furnish the necessary heat at a reasonable expense for fuel.

Many manufacturers rate their furnaces on the basis of a certain number of cubic feet of air the different sizes are able to warm, such as 10,000, 12,000, 15,000, etc. The only safe method for the furnace man to follow, if he accepts the ratings given, is to calculate the entire cubical contents of the building to be warmed.

Numerous rules for quick estimating are practised, a dependable one working on the basis that a square foot of grate should take care of 5,000 cubic feet of space. Figuring on this basis, we have in the residence described in our previous article, 20,580 cubic feet of space to heat, and 20,580 ÷ 5,000 = 401 square feet of grate necessary for the work, or a grate 27 inches in diameter.

One square foot of grate surface is estimated to be capable of caring for 300 square feet of glass surface or its equivalent, and we know that 4 square feet of wall surface has about the same cooling value as 1 square foot of glass. Turning to our estimate of sizes and exposures, we find we have 663 square feet of glass and 1,555 square feet of exposed wall; hence: 1,555 ÷ 4 = 338 + 663 = 1,051 square feet of equivalent glass; 1,051 ÷ 300 = 3.5 square feet of grate, or a grate about 25½ inches in diameter.

Still another rule totals up the area of all basement leader pipes, on the principle that the combined area should be from one and one-fourth to one and one-half times the grate area of the furnace, according to the character of the work. Note that for the residence illustrated the area of the basement pipes is 768 square inches, and we estimate a furnace having a 26 inch grate with an area of 530 square inches.

Select a furnace of only such height that proper pitch or elevation may be afforded the basement leaders, which should pitch upward from the furnace at least one inch in each foot of length.

In estimating the cost of this piping it is customary among some furnace men to figure on an average length of 10 feet for each basement leader—a rule-of-thumb method, the use of which should be discouraged—and the value of making a sketch or plan of the work is here apparent. The basement leaders should be erected and run with no abrupt turns. Long, circular bends or turns, as shown on Fig. 51, should be arranged for wherever possible, and, with a plan to guide one, it is possible to measure quite accurately the length of each leader.

For each first floor room we figure:

Basement leader......... (Size)......... (Length).........
Extra for bends.............. (If necessary)...............
Casing collar ....
Damper in pipe..
Register box ....

For the second or other upper floors we figure:

Basement leader......... (Size)......... (Length).........
Extra for bends............ (If necessary).................
Casing collar ....

Damper in pipe..
Riser (3' longer than height of ceiling).....................
Boot ....
Elbow ....

The length and size of smoke pipe should now be included, and do not forget to provide a damper for the same. The estimate sheet should show:

Smoke pipe—diameter, length, gauge iron, damper, elbows.

The cold air supply should next be estimated, and the following items made note of:

Cold air pit................(Under furnace)................
Cold air chamber..
Baffles in chamber................(If desired)..............
Cold air duct...
Damper ....

It is not essential that a printed estimate sheet be used, but if in such shape, the form will prevent the omission of items in making up the estimated cost of the work, although one figuring such work constantly becomes accustomed to setting down the items in proper rotation.

The cost should be made up as follows:

Furnace .... (Size) .... (Kind) ....
Furnace casing ....
Furnace pit..................(If necessary)...............
Registers and borders.....................................
(List of sizes, kinds and costs.)
Pipe and fittings...
(Here should follow a list, room by room, of all leaders, bends, collars, boots, elbows, etc.)
Smoke pipe and damper.....................................
Cold air chamber..
Cold air duct...
Cold air pit..
Covering of piping..
Carpenter and mason work..................................
Labor—tinner and helper...................................
Labor expenses ....
Freight and cartage.......................................
Incidental expenses ....

The above should form the basis of the cost of the job, to which should be added the percentage of profit desired, and in connection with this item of profit we would call particular attention to a very common error, viz.:

The average dealer, having ascertained the cost of the work as accurately as he can figure, will, if he desires a profit of 20 per cent., add this amount to his figured cost, and having secured

the contract, the cost being, say, $300, for $360, assumes that he clears $60 if he receives $360 for the work, and possibly relying on the report so frequently heard that it cost 10 per cent. to do business, will think his profit is $30. Not at all! Suppose that the cost of doing business is 10 per cent. (an estimate entirely too low). Remember this is not figuring on the cost price, but rather on the selling or contract price. Consider the volume of business done yearly as $25,000, and the expense of doing it $2,500. This is the 10 per cent. The contract price is $360, and 10 per cent. is $36, which must be added to the cost, making it actually $300 + $36, or $336.

Now, with 10 per cent. profit added, the contract price should be $336 + 10 per cent., or $369.60, and, as before stated, this is entirely too low, for the actual expense of conducting a business is seldom less than 20 per cent.

This charge is based on all the unproductive expenses of the business, such as rents, team and driver, office help and all other labor not included directly in a job, insurance, postage, interest on money invested, value of real estate, etc., etc. It is called the "overhead" expense of the business, and, as such, is chargeable to every article sold or every contract taken, as a cost.

Will our doubting readers figure up the volume of their business the past year, total their unproductive expenses for the same period, and then ascertain their overhead expenses? Do not be surprised if the rate equals 40 per cent. of the volume of business transacted, from which it must be appreciated that this is doubtless the most important item in making up an estimate.

CHAPTER VII

INTELLIGENT APPLICATION OF HEATING RULES

The movement of air under varying conditions should be the constant study of the furnace man, for only by a familiarity with this subject is he assured a satisfactory way out of the trouble which sooner or later will be met in the installation of his hot air work. In the foregoing articles we have touched upon the subjects of air movement and air velocities, and in a general manner have considered the flow of the heated air and also of the cold air.

It is possible to lay down certain rules governing the sizes of piping, registers, cold air supply, etc., but there never was and, moreover, never will be a rule to fit all cases; therefore, to make its use valuable the rule must be applied with good judgment, and this good judgment cannot well be exercised unless the interested person is familiar with and can adapt it to the conditions surrounding the work.

When estimating on a job of furnace heating it must be remembered that conditions prevailing in a section where the thermometer scarcely ever reaches zero are not the same as those prevalent in a more rigorous climate, say where a temperature of 25 degrees below zero is not unusual. Further, a hot air heating apparatus, planned and intended for a well built and consequently warm structure would not suffice for the same work if installed in a loose, poorly constructed building; therefore a rule-of-thumb method used in estimating for the former would not give adequate results for a building of the latter type.

We have dwelt upon this same subject from time to time in our preceding articles, quoting various rules, acting on the principle that information of such character cannot be consulted too frequently or discussed in too many different forms, inasmuch as it is the foundation of all good furnace heating practice.

The heat losses of a building determine the size of every part of the heating apparatus. The use of the heat unit in making

calculations is highly advisable and can be followed with advantage. The air delivered by the furnace should have a temperature not above 150 degrees, and 140 degrees is better. With this temperature at the furnace the rooms heated should be maintained at 70 degrees. The difference, then, between the temperature of the furnace and that of the rooms is 70 degrees, or, in other words, in maintaining this temperature in the rooms the air drops from 140 to 70 degrees, and in doing this amount of work each cubic foot of air delivers 1.1 heat unit.

Each square foot of single thick glass (and the full window opening as well as outside doors should be counted as glass) will cool 85 heat units per hour.

Each square foot of net outside wall surface in a building of frame construction (that is, deducting windows and doors) will cool approximately 20 heat units per hour.

The value of the cooling surface of brick walls varies according to their thickness. A 9 inch wall will transmit or cool 30 heat units per hour, a 13 inch wall 24 heat units.

The size of leader or the area of the hot pipes is, of course, determined by the amount of warm air required, and this is fixed by the amount lost from the room as well as by the temperature of the hot air at the register.

Working on the basis of the above data, the loss for glass surface will be $85 \div 1.1 = 77$ cubic feet. At a velocity of 300 feet per minute, each square inch of pipe area will deliver approximately 20 cubic feet of air per hour; therefore each square foot of glass will require $77 \div 120 = 41/64$, or about 2/3 square inch, and in like manner we find that each square foot of outside wall surface requires 1/7 square inch.

The hourly leakage of warm air from the room will about equal its cubical contents, requiring approximately 1/100 square inch of pipe area. The total pipe area necessary is therefore 2/3 of the glass surface, plus 1/7 of the wall surface, plus 1/100 of the cubical contents of the room, this rule applying to first floor rooms. The flow of air in the leader to a second or third floor room is probably 500 feet per minute, and proper allowance should be made for the increased velocity, which will afford a reduction of approximately one-fourth in the area of the leader.

For example, consider a first floor corner room 12 by 15 feet with a 10 foot ceiling, having three windows 3 by 6 feet in size.

Glass surface, $3 \times 6 \times 3 = 54$ square feet.

Net wall surface, $12 + 15 = 27 \times 10 = 270 - 54 = 216$ square feet.

Cubical contents, $12 \times 15 \times 10 = 1{,}800$ cubic feet.

$$54 \times 2/3 = 36$$
$$216 \times 1/7 = 31$$
$$1{,}800 \times 1/100 = 18$$

$36 + 31 + 18 = 85$ square inches of pipe area, or a pipe about $10\frac{1}{4}$ inches in diameter; therefore a 11 inch pipe should be used.

For a second floor room of similar size and exposure: $85 - 21$ (one-fourth of 85) $= 64$ square inches, or a leader pipe 9 inches in diameter.

The total area of all leaders should equal from one and one-fourth to one and one-half times the area of the grate.

The net register area should be 25 per cent. greater than the area of the pipe serving it.

Fig. 52—Automatic Air Damper.

Another very good rule for determining heat losses is based upon the assumption that one square foot of glass will cool one heat unit per hour for each degree difference in inside and outside temperature, and that the loss through exposed walls is one-quarter that for glass surface.

The rule is: Add one-quarter of the wall surface to the glass surface and multiply by 75 for rooms having a south or south and east exposure; by 85 if a north or north and west exposure for zero weather temperature, and by 100 if location is in a more rigorous climate. This will give the hourly loss in heat units.

There is a considerable variance in regard to the size of the fresh air duct. Averaging the area as given by several authorities demands that the area of the duct for cold air should equal 80 per cent. of the combined area of all warm air pipes leading from the furnace. We believe that the cold air supply should equal the area of all warm air leaders in order to distribute an abundance of pure air to the rooms heated, and while fuel

consumption will be slightly increased under these conditions, in our opinion economy at or from this point should not be considered.

In connection with the air supply, we desire to call attention to an automatic atmospheric air damper or regulator for controlling or restricting the movement of air where the movement is due to gravity or natural conditions.

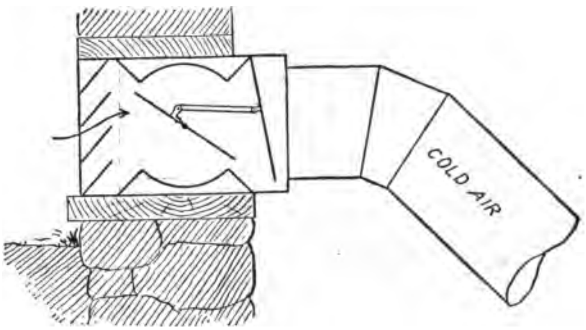


Fig. 53—Application of Damper to Cold Air Supply.

Fig. 52 illustrates a small regulator, 4 inches high by 12 inches wide, adapted for a capacity of 80 cubic feet per minute at a velocity of 300 feet. The primary or main blade moves from an open position to a nearly closed position and is actuated by a secondary or motor blade. The motor blade is located in a

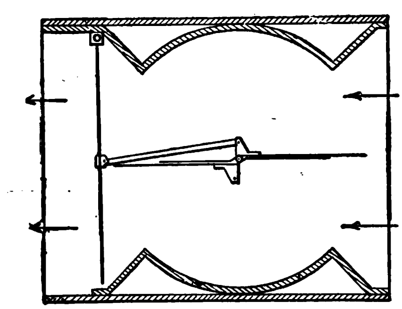


Fig. 54—Fully Open Position.

representative position to be acted upon by the velocity pressure of the passing air and works against the action of the adjustable weight shown at the right hand side. Both primary and secondary blades are of aluminum.

The opening in which the primary blade moves has circular

top and bottom, and the blade moves back and forth one-eighth of a turn, except on sudden impulses, when it may go as far as one-quarter of a turn.

This regulator was devised by an engineer at St. Paul, Minn., and its application to the cold air supply of a furnace is shown by Fig. 53.

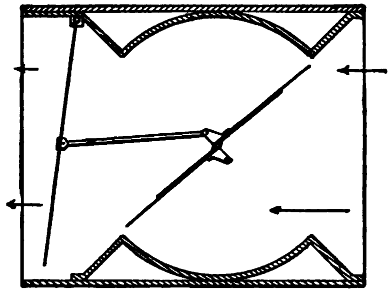


Fig. 55—Partly Closed Position.

At each of the two sides of the regulator are magnetic retarders to prevent the oscillation of the blade and so that the blade moves from one position to another steadily. The magnetic retarding device acts as a retarder with substantially no resistance and consists of an aluminum disc placed between the jaws of permanent magnets.

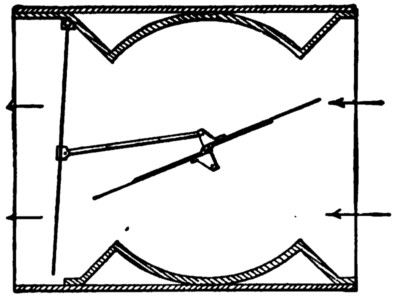


Fig. 56—Nearly Closed Position.

Figs. 54, 55 and 56 show the device with the main blade in a fully open, a partly closed and a nearly closed position. When the movement of air, either hot or cold, is placed under control to the extent made possible by this regulator, indirect ventilation can be secured with a greater degree of positiveness and satisfaction than is possible at the present time.

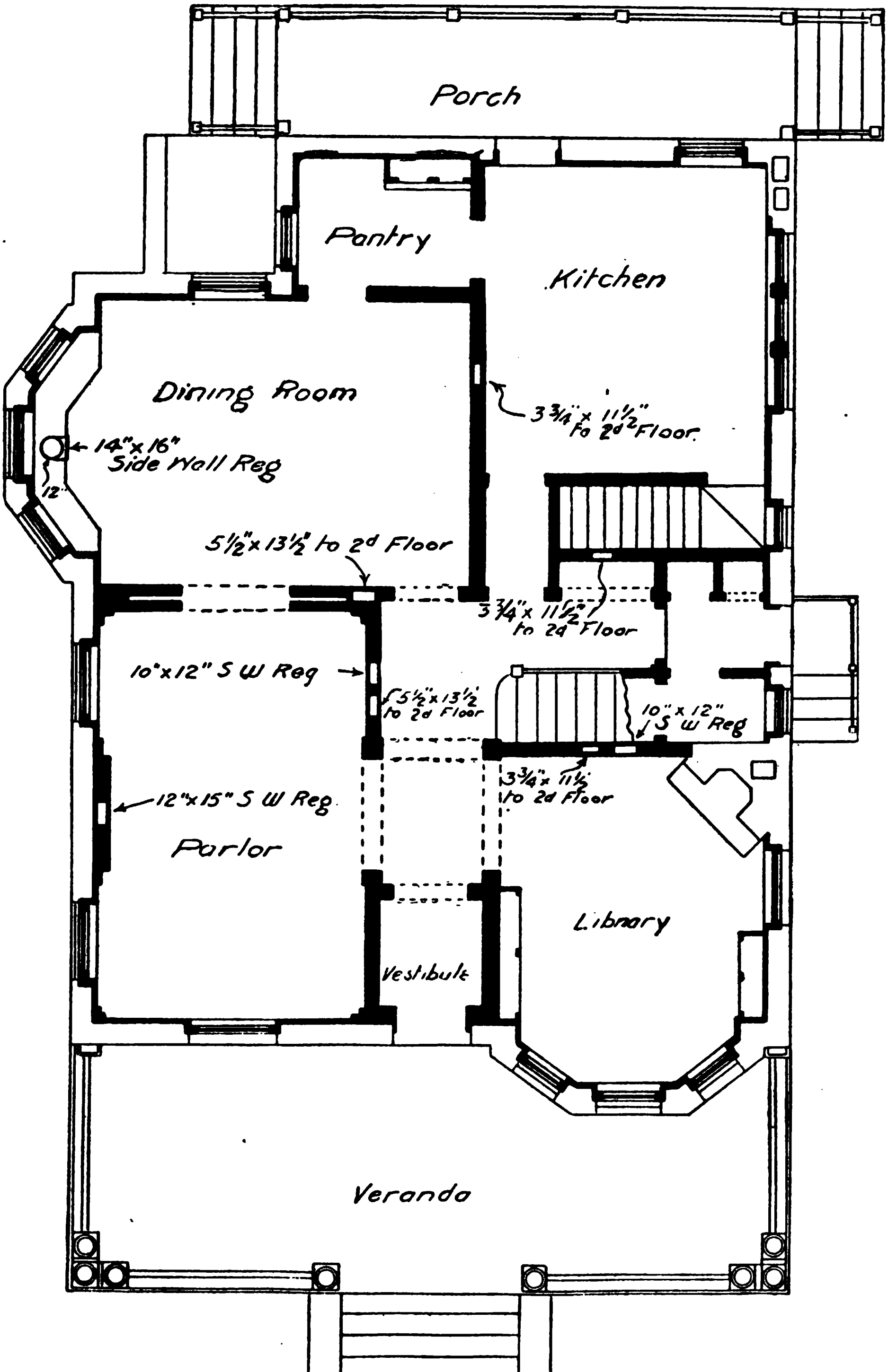


Fig. 57—First Floor Plan.

CHAPTER VIII

PRACTICAL METHODS OF CONSTRUCTION

All methods of direct heating depend in operation upon the infiltration of outside air to supply or replace the oxygen consumed by the occupants of the building and by the artificial lighting equipment. It is probably needless to add that the amount so secured is inadequate to maintain the air reasonably pure without, in addition, opening windows or doors, and the relief afforded by this latter method, while partially effective, is only obtained at a direct loss in fuel consumption.

With the ordinary form of furnace heating an abundant quantity of pure air is supplied when an outside air duct is used in connection with the apparatus. It is obtained without a recirculation of the air within the building, which is a desirable condition, for while recirculation assists the movement of the air, it does not assist the ventilation. If the furnace is of such capacity that the incoming outside supply can be warmed, when admitted to the rooms at a low temperature, and at the same time be under proper conditions of humidity, there can neither be any question as to the ability of such an apparatus to properly heat an average sized residence or building, nor any question as to the purity of the air it supplies.

We have known many furnace men to advocate the principle of taking the air supply to the furnace from all, or a part, of the basement, claiming that the recirculation of the air to the basement in this manner not only purified it by reason of the natural leakage or infiltration of outside air into the basement, but also produced this result without the loss of the heat units necessary in warming cold outside air. However, we strongly condemn this practice. It is impossible to obtain air too pure for breathing, or, we might add, too much of a supply, and, according to our belief, no better results can possibly be secured than those obtained from the use of a ventilating stack into which foul air ducts from each room are connected.

As has been already stated in these articles, the air in a residence sparsely occupied and lighted with electricity is but slightly contaminated, and we know of no reason why such air should not be recirculated. The circumstances surrounding each individual job of furnace heating should determine the manner in which the apparatus should be installed, and, as an example, we refer to the residence used to illustrate this article. The floor plans (Figs. 57 and 58) show the first and second floors of an average sized dwelling containing eight rooms, with the usual halls, bath room, and pantry, which is located in a neighborhood free from dust and dirt, and the evil influences of smoke and gases emanating from factories or mercantile establishments.

The level of the first floor is some 10 feet higher than the street, from which it is separated by a lawn, perhaps 100 feet deep, affording conditions which favor a pure air supply. The fireplace in the library furnishes an outlet for the impure or contaminated air.

The basement plan (Fig. 59) shows the installation of the furnace, cold-air chamber and duct, and the warm-air leader pipes, the sizes of all being plainly marked.

The cold air is admitted to the cold-air chamber through a comparatively small opening, the cold-air duct being nearly twice the area ordinarily used in order that in zero weather the harsh effect prevailing when admitting a volume of frosty air to the furnace may be overcome. In mild weather an abundance of slightly warmed air is carried to the rooms.

The sizes of risers and registers are shown on the floor plans, and attention is called to the method of bringing the warm air supply to the parlor through a register located in the mantel, as well as to the location of the register, under window seat in the dining room.

This is an example of furnace heating such as is in every-day use during cold weather, and the conditions so ably handled by the furnace contractor reflect great credit on his judgment and ability. We consider the job worthy of study and comparison by furnace men.

It seems as if at the advent of every fall season there is needed a series of articles setting forth and explaining the few important factors of furnace installation. Whether this need is due to the fact that the tinner has been so busy with roofing and spouting during the summer months that he has forgotten the many things learned during the past winter, or whether the presentation of old familiar information in new dress is required to awaken him to a study of the latest ideas in such installations, we do not know, but we do learn from observation that as soon as some new idea or method is evolved and offered to

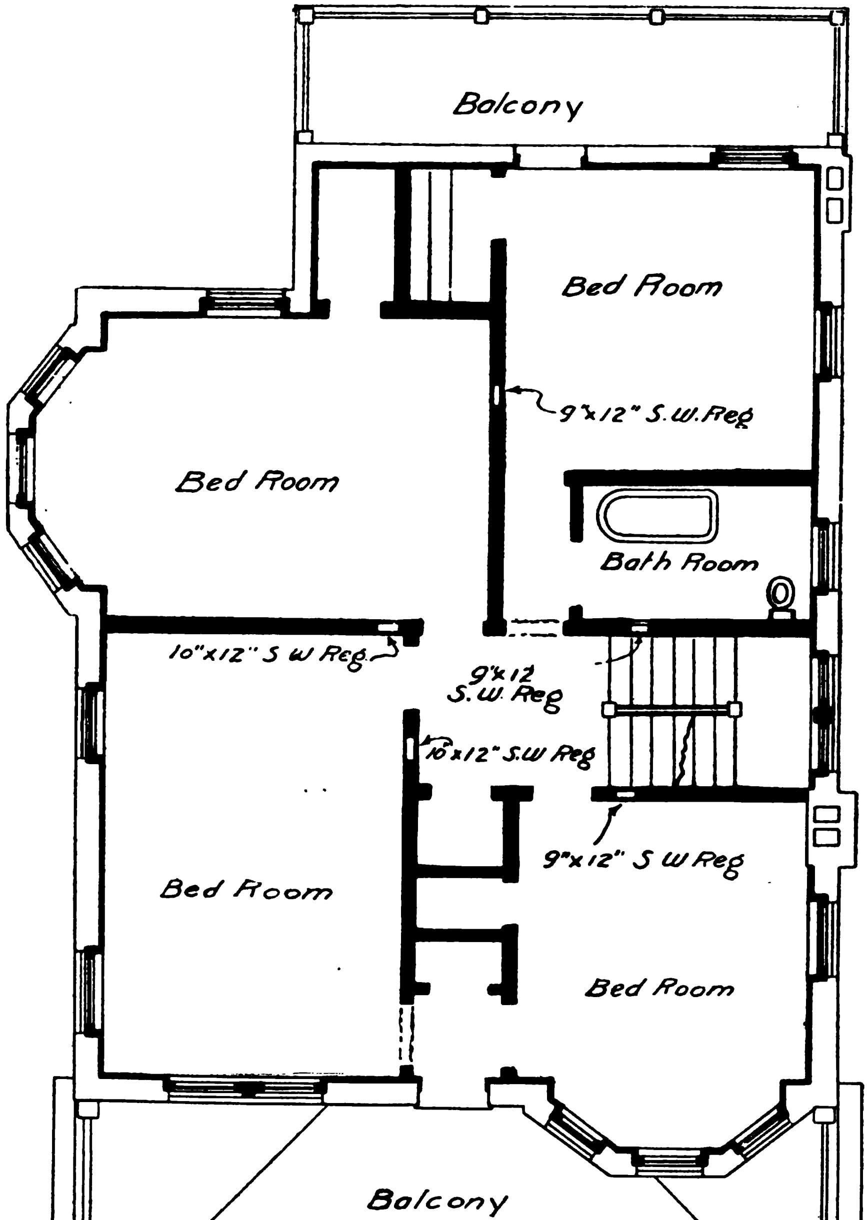


Fig. 58—Second Floor Plan.

the trade, many of the old-time tinners at once claim Missouri as their home and ask to be shown.

Experience has demonstrated that a furnace job in order to be successful in operation must be of sufficient size (both in the furnace and accessories used) to perform the necessary work well under the most adverse circumstances; also, that it is important for it to be so constructed that the air may travel freely and without unnecessary friction from outside the building through the cold-air chamber, cold-air duct, furnace, leaders and risers to the registers, if the building is to be heated easily and economically.

In order to arrange for this result we must follow the air from its introduction into the building to insure that all sharp angles or abrupt turns in the piping are eliminated and that the connections of the leaders with the risers or stacks are made with boots of such shape that the air is not retarded at the base of the riser. The old practice of connecting a round pipe leader directly into a shallow rectangular heat flue cannot be too severely condemned.

The air moves under a very slight pressure, a slight obstruction materially retarding its movement, and while the use of fittings of special form will add considerably to the cost of the job, the successful furnace man appreciates that correct practice calls for their use and acts accordingly, often refusing to install the work if the cheaper competitive methods are desired.

It is the desire for cheapness on the part of building contractors and the readiness of some furnace men to cater to this class that have brought furnace heating into disrepute. How is it possible to convince interested people of the superior advantages of furnace heating when the public mind is poisoned by the results of work of this character? The proper method to pursue in order to raise the standard is to absolutely refuse to install a job except given at a price which will warrant the use of material, good in quality and up to date in design.

A certain large commercial house adopted as a slogan the phrase, "The quality is remembered long after the price is forgotten." This motto might well be hung with advantage over the desk of the furnace man to be kept in mind when estimating on and installing furnace work.

As an example, consider the job illustrating this article. Figure over the work from the data given as the job should be installed, and then make an estimate based upon cheap competitive work. The difference will be under $100, representing at prevailing interest rates $5 or $6 a year. The former job will prove entirely satisfactory in service, with a minimum amount of attention and fuel consumption, giving a maximum of comfort and

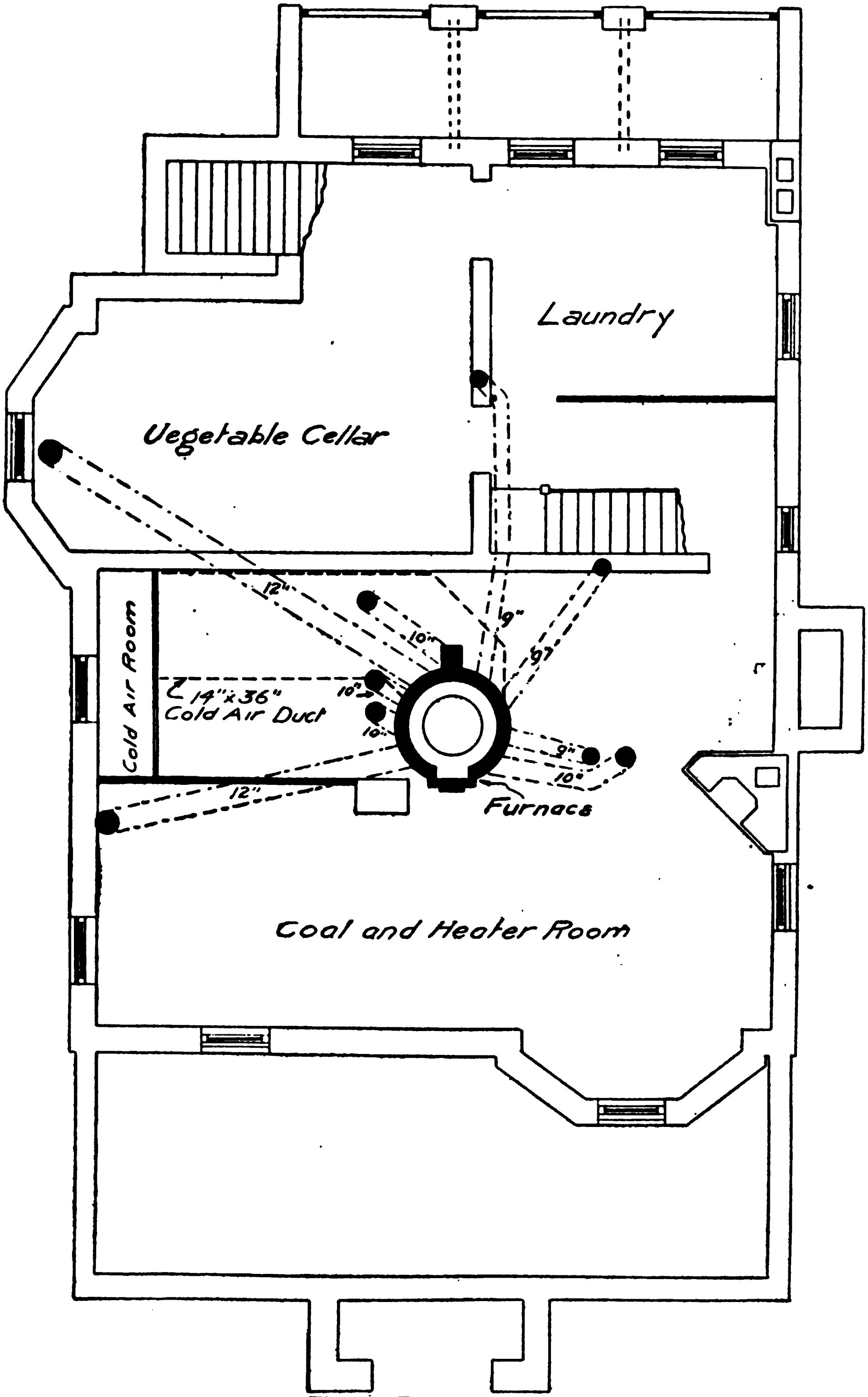


Fig. 59—Basement Plan.

convenience. The latter will prove expensive in operation, will require close attention, and will consume at least 25 per cent. more fuel, to say nothing of the unsatisfactory heat produced.

The owner will readily pay the difference for the better job, if these facts are properly set before him. It is therefore to the financial interest of the dealer to become sufficiently familiar with his subject to intelligently present these advantages.

School House Warming and Ventilating

It is said—and truthfully so—that a man never stands still in his profession. He either advances, becoming more and more proficient, or loses ground and finally becomes a "back number."

There are many furnace men—good mechanics—who, while entirely competent to install almost any kind of a warm air system once it is designed or laid out, will balk and appear ignorant when questioned as to air change, the requirements for ventilation, the State laws governing school house warming and ventilation, etc.

We illustrate an example of school house warming and ventilation designed to comply with the requirements of a State law which demands that each pupil in each school room shall be supplied with not less than 30 cubic feet of fresh air per minute. This amount of air is considered as a minimum, some cities demanding as much as 50 cubic feet per pupil per minute.

The proper ventilation of school rooms is now considered as important as the heating of them, and six States—Massachusetts, New Jersey, New York, Pennsylvania, South Dakota, Utah and Virginia—require the enforcement of a law demanding 30 cubic feet per minute per pupil.

Main, Montana, North Carolina and Vermont require the approval of school houes plans, and South Carolina, Minnesota and Wisconsin will make no State appropriation to school districts who do not submit plans which must be approved by the Board of Education, all of which goes to show that the various States are falling into line and adopting the standard set by Massachusetts, requiring 30 cubic feet of air per pupil per minute.

Can this be accomplished when a furnace is used for heating? Yes, but not with the furnace alone, as a purely gravity system will not act with sufficient rapidity to produce the necessary change of air.

By employing the fan-furnace system for such service a definite air change may be provided, and this system we illustrate herewith.

Each school room is heated and ventilated. The halls and cloak rooms are heated, but not ventilated.

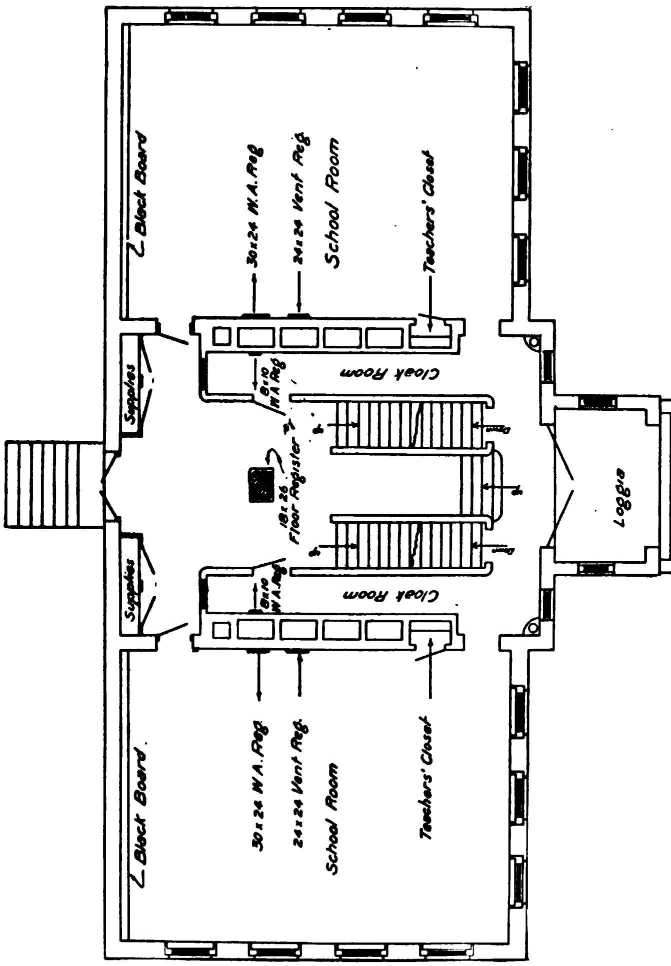


Fig. 60—Plan of First Floor.

Fig. 60 shows a plan of the first floor, and Fig. 61 a plan of the second floor. Each floor contains two class or school rooms, 24×32 feet in size, with a ceiling 13 feet 6 inches in the clear, and each room is designed to accommodate 45 pupils.

To determine the amount of fresh air to be supplied we proceed as follows:

45×30 (cubic feet per minute) $= 1{,}350$ cubic feet per room per minute.

$1{,}350 \times 4 = 5{,}400$ cubic feet per minute for all four school rooms.

To provide for and distribute this air in the volume required a 30 inch motor-driven disc fan is installed, as illustrated on the basement plan (Fig. 62). This fan, running at the medium speed of 450 revolutions per minute, delivers 6,700 cubic feet of air per minute, and requires about ½ h. p. to operate it. At maximum speed, or 575 revolutions per minute, the fan delivers 10,000 cubic feet of air and requires 1 h. p.

This shows the size of fan to be sufficient for all conditions of service, and for easy and economical operation a 1½ h. p. motor is installed.

The speed of the fan is regulated from a rheostat located in the room of the principal of the school.

The warm air registers, 24×30 inches in size, are located about 8 feet from the floor. The fresh air entering each school room under a slight pressure is diffused, and, seeking the cold walls, is slowly chilled as it settles to the floor, where it is drawn off through 24×24 inch registers into the ventilating flues. These registers are located at the floor line, and the change of air is accomplished without any drafts or discomfort to the occupants of the room.

The boys' and girls' toilets in the basement are ventilated by means of special window ventilators.

The cold fresh air enters the cold air room in the basement through two windows having hinged sash, and the fan is placed in a 32 inch duct leading to the pit under furnaces. A by-pass, 30×36 inches, in the form of a duct, connects the cold air directly from the cold air chamber to the furnace pit. This is for use when the fan is not in operation, and it is provided with a damper which is closed when the fan is in use. This duct is not shown on the basement plan. It is located beneath the floor, immediately under the galvanized duct used in connection with the fan.

In planning the building the architect had provided four flues, 18×36 inches in area, and one flue 16×16 inches in area, to serve the rooms on each side of the hall. These flues are made

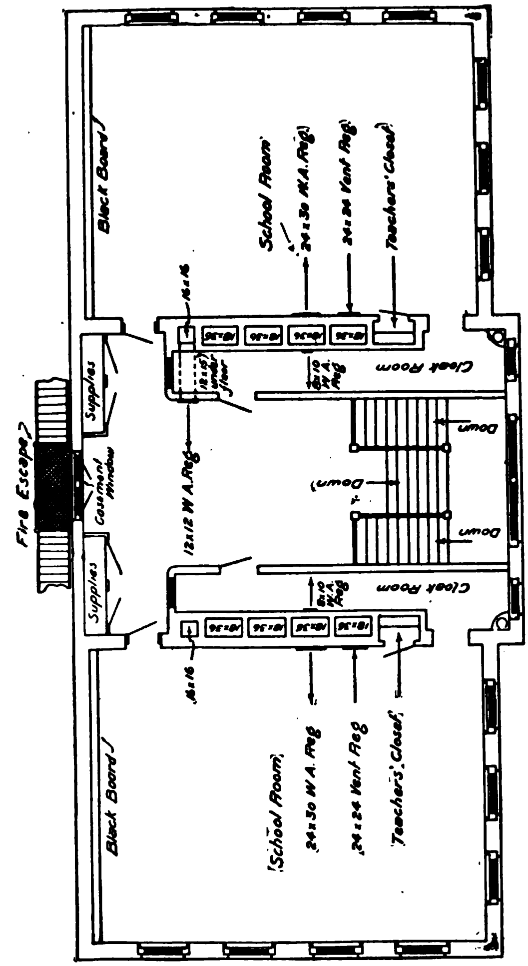


Fig. 61—Plan of Second Floor.

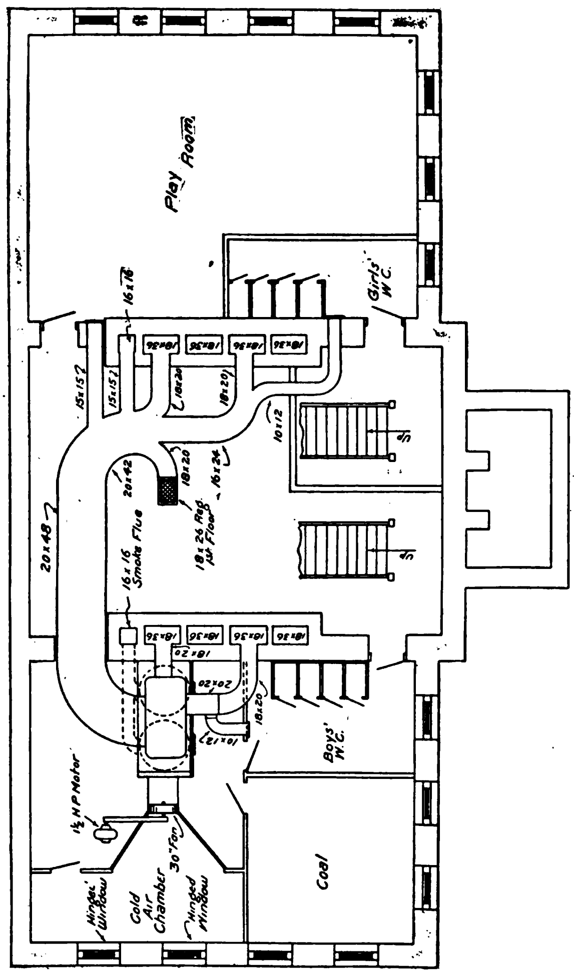


Fig. 62—Plan of Basement.

use of for warm air and ventilation, as shown by plans, and while they are somewhat larger than is necessary, their largeness is a good fault.

The basement rooms which receive heat from the system are the play room, girls' and boys' toilets.

The construction of the air pit under the furnaces is a particular feature of the installation. The furnaces proper are supported on brick piers, which are built in the pit under the center of each furnace, and a deflector in the pit divides the cold air supply uniformly to both furnaces, each of which has a 35 inch pot, is encased in brick and has a cast iron front.

The top of furnaces is covered by a galvanized iron hood or top casing, from which the hot air trunk lines are taken, as indicated on the plan of the basement.

The installation of two furnaces is desirable, as during periods when but little warmth is necessary and it is required only to temper slighty the incoming fresh air, one furnace will produce all of the heat desired, this arrangement making a decided reduction in the amount of fuel consumed.

When estimating work of this character and figuring for a certain definite change of air, there are some facts in connection with the selection of a fan which should be considered.

The speed of the fan conditions the volume of the air delivered; that is, the volume varies directly as the speed. Doubling the number of revolutions of the fan doubles the volume of air delivered.

The pressure varies as the square of the speed; that is, if the speed is doubled, the pressure is increased four times and the power required to drive a fan varies as the cube of the speed. For example, if the speed is doubled, the power required is increased eight times.

It is therefore more economical to use a large fan at slow speed than a smaller fan at greater speed, and the mistake of selecting too small a fan should not be made. The motor for operating the fan may be directly connected to the fan or belted to the fan, as illustrated on the basement plan.

CHAPTER IX

WHAT CONSTITUTES GOOD FURNACE WORK

Having so frequently been asked the question, "What do you mean by good work?" or "What constitutes good furnace work?" we will proceed to consider a number of features which characterize really good furnace work, and then ask ourselves if we are conforming to such a standard.

A good firm foundation of masonry, whether of bricks or of concrete, is the first provision for a good job. On new work the foundation for the furnace, and also the cold air pit, should be built before the cellar is cemented, and if the cold air is to cross a section of the basement below the floor level, this trench should also be constructed before the concrete for the floor is put down.

Both pit and trench should be constructed of hard brick laid in cement, or of carefully mixed concrete. It is better to build the walls of the pit of brick laid in cement. The top of the trench may be built of concrete laid over wood forms or reinforced with perforated sheet steel now obtainable for the purpose.

Dust Discharge

A frequent complaint about furnace heating is that dust is discharged into the rooms. Ninety-nine per cent. of this trouble is caused by the absence of a suitable foundation, the furnace resting on the cellar bottom, or upon a poorly constructed foundation.

The heat from the ash pit will soon dry the earth bottom so that the dust from it will be carried upward into the rooms, or if a poorly constructed or uneven foundation is used, the joints of the furnace will open up, due to the racking of the castings when shaking the grate. Not only is this a source of annoyance, but it also shortens the life of the furnace, and renders the castings liable to cracking, due to unequal expansion of the

metal. When a furnace is set upon an even, smooth foundation the parts will fit in their proper places without straining.

The Casing

Having properly set the furnace, the next item of importance

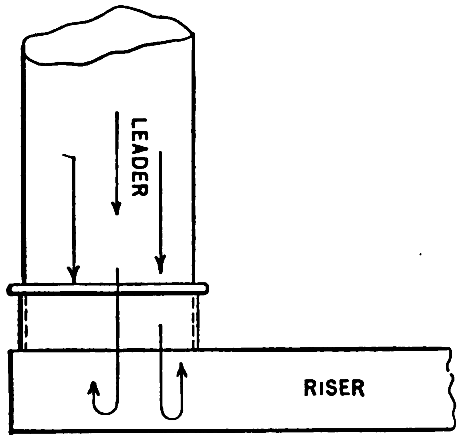


Fig. 63—Connection with Riser Improperly Made.

to consider is the casing. Some furnace men prefer a double casing—the inner one of black iron and the outer one of gal-

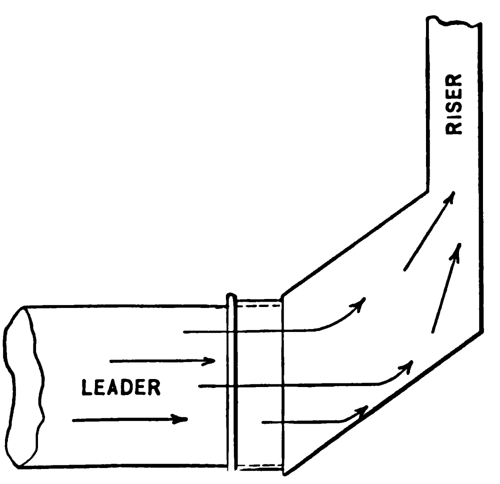


Fig. 64—A Connection Better Than That Shown in Fig. 63.

vanized iron with an air space between—while others prefer a single casing, covered on the outside with asbestos and lined on

the inside with bright tin, plain or corrugated. Either method seems to us a mark of good work. The practice of encasing the castings in a single casing is a mark of cheap work and should be condemned. We know of some furnace men who use the single casing and cover it with a black iron casing, leaving an air space 1 to 1½ inches between. This shield serves to confine the heat and increase the efficiency of the furnace.

The Furnace Top

The furnace top has been discussed in a former chapter, but we would say, however, that a top with a reflector or cone in

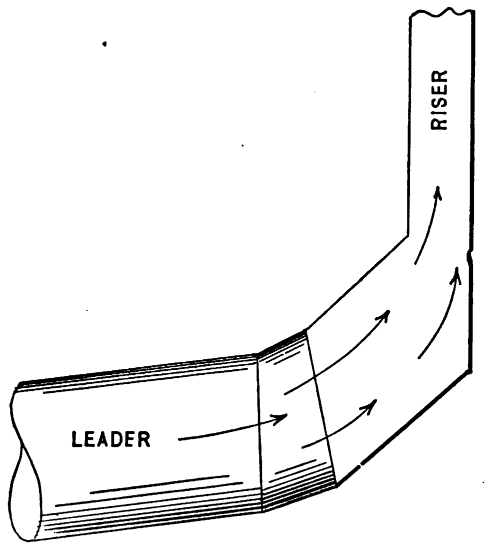


Fig. 65—The Best Method of Making Connection.

the center which throws the rising hot air toward the outer circumference of the casing is to be preferred to any other type. The warm air pipes may be taken from the top or on a slant, as the height of cellar and character of the job will allow. The cone fastened to the under side of the top provides an air space in the center, making the insulation of the top by covering a comparatively unimportant matter.

The Piping

The hot air pipes or basement leaders are essentially an important part of furnace work, and in laying out this part of the work the furnace man should keep in mind the fact that the installation of the piping, if not properly done, will cause the apparatus to prove a failure.

In planning the piping every effort should be made to eliminate friction. This may be accomplished by shortening the runs and dispensing with all abrupt angles. Every bend increases friction and reduces the velocity of the air current.

Concerning Bends

Of course, bends are unavoidable, but it is a mark of good

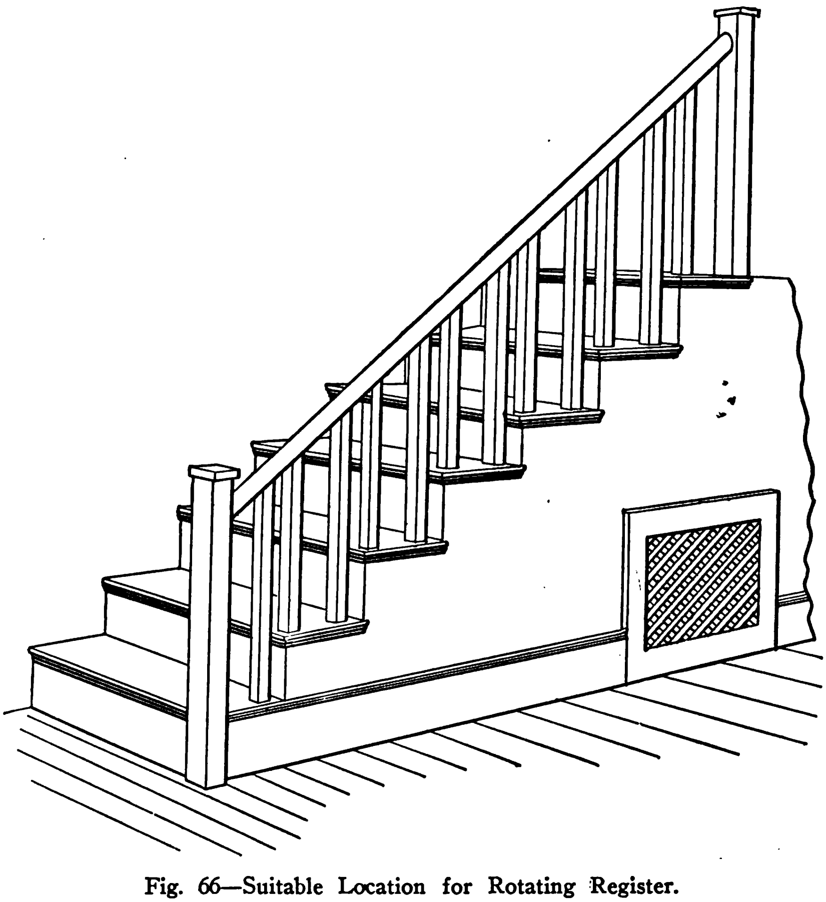


Fig. 66—Suitable Location for Rotating Register.

work to find all bends made with a long sweep or easy turn. It requires but little obstruction to turn a current of air which, owing to its elasticity, will rebound when striking a surface at a right angle. Fig. 63 of the annexed diagrams illustrates a connection to a riser improperly made. The direction of the

air is indicated by arrows. Fig. 64 shows a modified form of connection, showing an improvement in the direction of air currents. Fig. 65 shows the best method available, and the easy passage of the air into the riser will be quickly noted. Such methods of making connections indicate good work and a knowledge of the handling of air on the part of the furnace man.

Heating Surface

Thus far we have said nothing regarding the value of large heating surface—i. e., a good generous size of furnace, particularly in regard to the fire pot and grate. A job may be ever so carefully installed, but if it be lacking in capacity it will prove inadequate and wasteful of fuel. Good work demands an economical furnace—one whose grate area is sufficient to hold enough coal to give off the necessary heat units with slow combustion, and a pot and drum, or heating surface, sufficient to warm the volume of air demanded without heating to excessive temperatures, and in this connection it is well to remember that the higher the temperature of the furnace the greater will be the waste of heat in the chimney.

We favor the recirculation of the air in the principal rooms of the first floor. We know that many wise ones condemn this practice, yet there seems to us no reason why the air from the living rooms and hall should not, under ordinary conditions, be returned to the furnace for reheating, as it is not contaminated to any perceptible extent.

When rooms in one part of the house are "thrown together," as the parlor, reception room, library and hall, one large rotating register placed at some central point, preferably in the hall, will be found sufficient. The staircase is a particularly good place for the installation of the rotating register, as the space under the steps allows of making a large galvanized duct connection to the register. Fig. 66 illustrates the idea.

The extra expense of installing the apparatus in the right manner is money well invested—in fact, like putting the money in a bank which pays large dividends.

Added Cost of Hard Firing

If a heating system of scant capacity or of poor construction is installed, which necessitates hard firing, with the attending waste of fuel, it is not uncommon to find such an apparatus using from 20 to 30 per cent. more fuel than would otherwise be found necessary.

The additional expense of installing an adequate and properly constructed apparatus would at this rate be paid for in four

or five years, and the annoyance of using a poor apparatus for that period would have been eliminated. There is absolutely no excuse for doing poor work or installing inadequate material when the argument of dollars and cents can be so strongly used with possible customers, and good furnace men are alive to this fact.

Importance of Installing High Class Work

Notwithstanding the fact that the makers of hot-air heating apparatus, the heating engineers, physicians and others in authority, who have devoted their time and attention to studying the conditions and results surrounding cheap furnace work, advocate and prove the need of ventilation and the circulation of air in connection with furnace heating, the sheet metal worker or furnace man unfortunately continues to figure and install cheap, unsanitary and unhealthful work, and when asked the reason, will invariably give as an excuse that the owner will not pay the additional price required for any other system. He may add, further, that his business rival will surely figure on doing a cheap job, and thus, by reason of the bugaboo of cheap competition, the furnace dealer will exert no effort to raise the standard of furnace work, fearing the possible loss of a contract.

We wish that it were within our power to impress upon the trade the fallacy of such reasoning, and that we could clearly show to the contractor the damage he is doing to his business standing in the community and to his reputation as a heating contractor by installing cheap and inferior work.

A job or two may be lost by taking a stand against and refusing to install low-priced work, but very soon a comfortable business of the right sort will have been established.

As an example of good furnace work, we show the basement and floor plans of a compactly built two-and-a-half-story suburban residence. The first and second floors are of cement construction, and the third or half-story is of frame work.

Fig. 67 illustrates the first floor plan, showing four rooms and a pantry. The reception room, living room and dining room are to be warmed and ventilated, while the kitchen is to be ventilated, but not warmed.

On the second floor (Fig. 68), four bedrooms and two bathrooms are to be heated and ventilated, and on the third floor, the plan of which is not shown, a bedroom is also to be similarly supplied.

The living room and dining room on the first floor, and the bedroom, over dining room, on the second floor, are ventilated by means of open fireplaces.

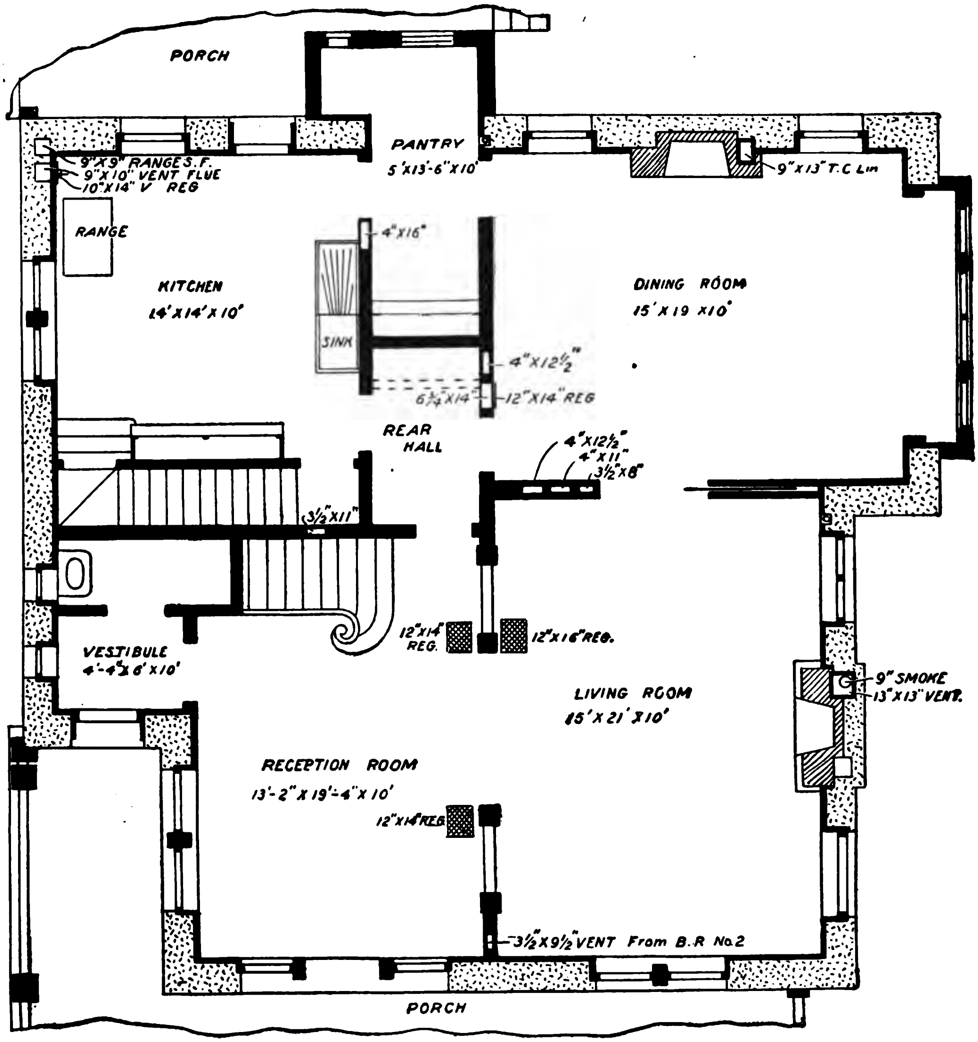


Fig. 67—First Floor Plan.

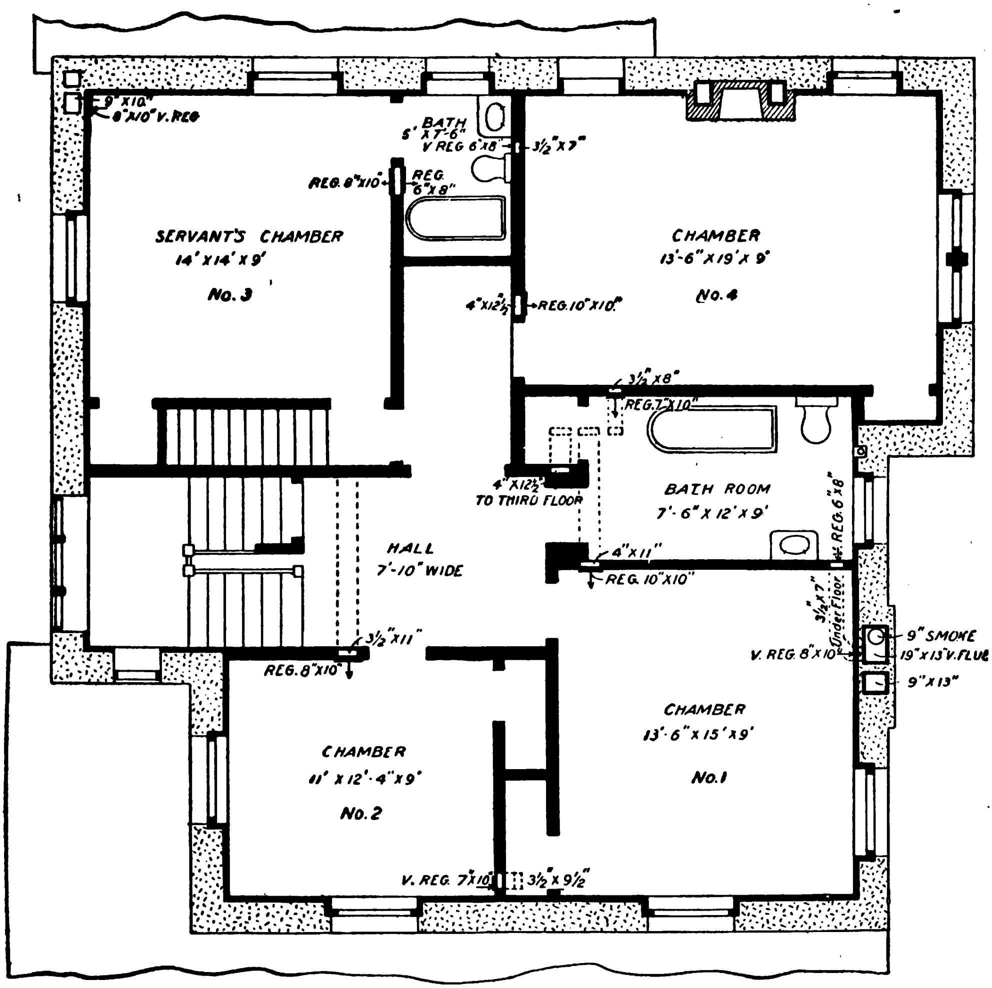


Fig. 68—Second Floor Plan.

The servant's bedroom and bathroom are ventilated by connecting the ventilating ducts with a 9 × 10 inch ventilating flue, built against the kitchen smoke flue, from which it is heated.

The ventilating ducts from all other rooms connect into a 13 × 19 inch vent flue, through which a 9 inch terra cotta smoke flue is carried. This is the smoke flue which serves the furnace. The ventilating flue is carried up through the first story 13 × 13 inches in size, being enlarged before the ventilating ducts of the second floor are connected into it. The support afforded the tiling in carrying the weight of it by this method of construction is a particularly good feature.

The kitchen is not included in the above arrangement. At a point near the ceiling this room has a 10 × 14 inch ventilating register connected into the 9 × 10 inch vent flue, mentioned above, for the purpose of carrying ofl the steam and odors of cooking and also the excessive heat from the range, and it is utilized in both summer and winter.

The basement plan, on which is shown the furnace, duct work and the arrangement for supplying fresh, cold air is illustrated by Fig. 69.

The following is a schedule of the sizes and description of all pipes, ducts and risers; the location and sizes of all registers are given on the plans, and require no further explanation:

SCHEDULE.

	Warm air, cellar pipe, in.	Warm air, flue, in.	Ventilating duct, in.	Warm air, register, size, in.	Description.
First Floor.					
Living Room	11	6¾ x 14	....	12 x 16	Floor
Dining Room	11	6¾ x 14	....	12 x 14	Special baseboard
Reception Room and Halls	2--10	....	....	2--12 x 14	Floor
Kitchen—Ventilated at a point near ceiling only.					
Second Floor.					
Bedroom No. 1.......	7½	4 x 11	3½ x 11	10 x 10	Sidewall
Bedroom No. 2.......	7	3½ x 11	3½ x 9½	8 x 10	"
Bedroom No. 3.......	9A	4 x 16	3½ x 11	8 x 10	"
Bedroom No. 4.......	8	4 x 12½	4 x 11	10 x 10	"
Bath	6	3½ x 8	3½ x 7	7 x 10	"
Serv. Bath	A	....	3½ x 7	10 x 10	"
Third Floor.					
Bedroom No. 5.......	8	4 x 12½	4 x 12½	10 x 10	"

The method of ventilation and the size and kind of ventilating registers follow:

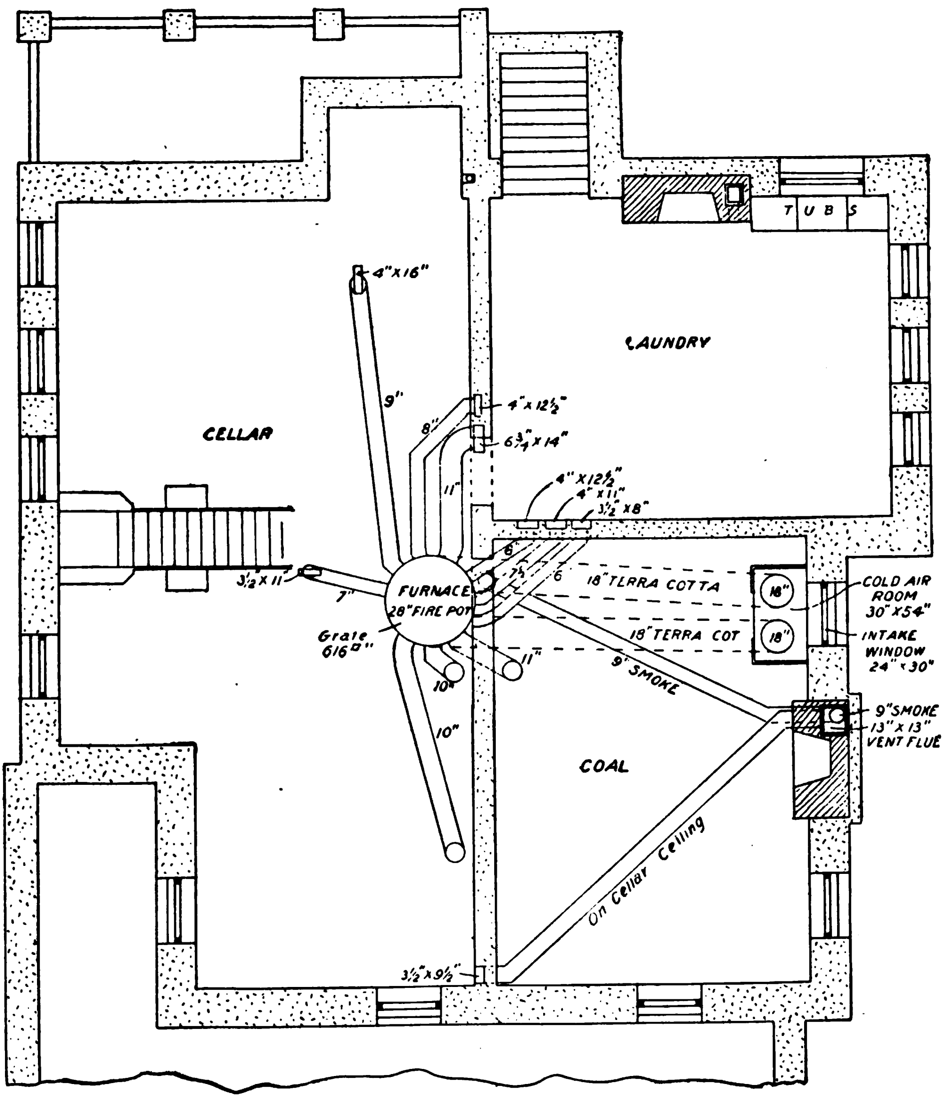


Fig. 69—Basement Plan.

	Ventilating register, size, in.	Description.
First Floor.		
Living Room	......	Open fireplace
Dining Room	......	" "
Reception Room and Halls	......	....
Kitchen	10 x 12	Sidewall
Second Floor.		
Bedroom No. 1	8 x 10	"
Bedroom No. 2	7 x 10	"
Bedroom No. 3	8 x 10	"
Bedroom No. 4	10 x 10	Open fireplace
Bath	6 x 8	Sidewall
Servants' Bath	6 x 8	"
Third Floor.		
Bedroom No. 5	10 x 10	"

In building a ventilating chimney of the character shown, it should be lined with terra cotta, in order that it will be perfectly smooth and also be able to retain the heat from the smoke flue which passes through it. The plan of the flue shown on the present job is clearly shown on the second floor plan, Fig. 68.

The cold air is admitted to the cold air chamber through a 24 × 30 inch screened opening in basement window, and baffle screens for filtering this supply should be provided in the cold air chamber.

To obtain the practical value of this article, we ask the furnace man to make his own estimate on this work, as herein recommended, and then to estimate for an ordinary form of cheap furnace heating for the same house. It is understood that the owner builds the ventilating chimney and the ventilating flue adjacent to the kitchen smoke flue, and that all other materials and labor are to be furnished by the heating contractor.

If estimated correctly the figures will show a difference of approximately $185, or a total difference, when including the cost of the flue, of about $250.

The difference in the results obtained from increased warmth and the comfort and healthfulness of a perfectly heated and ventilated home cannot be measured when compared with those secured from cheap work. Cleanliness and freedom from dust are assured the housewife with the former, and finally, as of vital interest to our readers, the installation of such an apparatus is a standing advertisement to the furnace man.

CHAPTER X

VENTILATION

The sciences of heating and ventilation are inseparably linked, and in the construction of a home, both should be considered jointly and proper provision made for the installation of an apparatus which will not only heat but ventilate as well. Professional men and laymen throughout the country are awakening to the importance of ventilation, and a word about it and its value will help to spread a proper understanding of its importance.

By ventilation is meant the process of changing or renewing the air within a room or building in order that the supply may remain sufficiently pure for breathing purposes. This statement indicates to us several facts: First, that ventilation is a method; second, that air confined within a room or building becomes foul and unfit for breathing; and, third, that pure air is necessary to sustain life.

Ventilation is a subject which until recent years has commanded too little attention from those who should be vitally interested, and the acquisition of an adequate system of ventilation in connection with the heating system is not now the luxury it once was considered—it is a necessity of today. The ventilation of a home is even of more importance than the heating of it, and we are coming to realize this, making provision for it as we recognize its worth, and the time is approaching—and that not far distant—when no dwelling of any size, or of the least importance, will be constructed without provision being made whereby the occupant may periodically remove the foul air and admit a pure supply.

That we may the more readily comprehend the many phases of this important subject, let us determine, if possible, what air is and note the properties of its composition. Air is an invisible liquid we call atmosphere, which surrounds the earth in a belt

several miles in thickness. It is invisible (we cannot see it); it is transparent (it does not obstruct our vision); it is insipid (we cannot taste it); it is inodorous (pure air we cannot smell).

It is composed principally of oxygen (one part), nitrogen (about four parts), and a very small proportion of carbonic acid gas and watery vapor. The volume of carbonic acid gas is from two to four parts in 10,000. The amount of vapor in the air is conditioned by the proximity to a body of water or the temperature of it.

Oxygen is the life-sustaining quality of the air. The nitrogen is necessary to dilute it, and the carbonic acid gas to rarify and purify it. Carbonic acid gas or carbon-dioxide is poisonous, and will, when present in the air in any considerable quantity, cause dullness, headaches, and produce fainting spells. This condition is noticeable in a room in which the air contains 10 parts in 10,000. Frequently the air in a crowded hall or public room is vitiated to the extent of 25 or more parts in 10,000, rendering it so unfit for breathing that persons having delicate constitutions will faint. This is also true of many factories or workrooms in which a large number of laborers are employed. Air breathed or inhaled into the lungs of people under conditions such as these, inhaled into the room, and breathed over and over again, is more or less laden with the germs of disease, which is all the more deadly should any of the persons present be suffering from a malignant affliction.

Carbonic acid gas is the result of all combustion. Oxygen is the life-giving quality in the atmosphere. The oxygen in the air of a room is consumed by the burning of candles, coal oil in lamps or stoves, and by gas. Occupants of a room by breathing consume the oxygen, and their exhalations are full of carbonic acid and other poisonous gases. If a man be shut up within a small, tight enclosure, his breathing will consume the oxygen, and the poison and gas from his exhalations will soon act to poison and suffocate him.

The amount of carbonic acid gas in the air we breathe should never exceed six parts in 10,000, and when present in a greater proportion it will cause headache and a feeling of stuffiness. Relief from this condition in the form of ventilation may be had more cheaply by the combination of a ventilating apparatus and a warm air furnace than by any other method, and we shall endeavor to make this plain to our readers as we progress with this discussion.

It is well that we fully appreciate how vastly improtant is the necessity for providing pure air to those who are compelled to labor or remain indoors. The vitiation of the air is not caused entirely by the respiration from our bodies, although it is a matter of record that from 1½ to 2½ pounds of water are daily evaporated from the surface of the skin of a person not actively engaged in work of recreation—that is, a person in still life. Another form of vitiation is the burning up of the oxygen in the air by gas lights, coal, coal oil lamps, or candles. A flame to which no oxygen can reach will sputter and die out.

The mechanics of the sheet metal trade will understand the need of pure air from some statistics recently compiled. These figures were given by medical authorities, after diligent research, and are to be relied upon. Of the deaths of those between 15 and 45 years of age in the United States last year, 28.4 per cent. died from tuberculosis or consumption. The death rate among certain classes of labor due to consumption is:

Marble and Stone Cutters	541 of every 100,000
Cigar Makers	479 of every 100,000
Printers	453 of every 100,000
Servants	430 of every 100,000

Formerly the percentage of death from consumption among cigar makers headed the list, but the International Cigar Makers' Union, a progressive labor body, by agitation and an aggressive campaign for light and air and more sanitary workshops, has reduced the percentage of deaths from this disease more than 50 per cent. in the last ten or fifteen years.

This, then, is the need of proper ventilation, and we shall endeavor to show how adequate ventilation may be provided by the proper installation and use of a hot-air furnace. The amount of fresh air necessary to supply varies somewhat with the conditions and use of a building, depending, of course, upon the use to which the building is to be put. Dr. Billings, an authority on ventilation, estimates as follows:

Kind of Building.	Cubic Feet Per Hour.
Hospitals	3,600 ft. per bed
Assembly Halls	3,600 ft. per seat
Workshops	2,000 ft. per person
Theaters	2,000 ft. per seat
Office Rooms	1,800 ft. per person

The schedule given applies to buildings with no contamination of the air except from the respiration of the occupants and the burning of the oxygen due to gas lighting.

Another authority states that the amount of carbonic impurity given off or excreted by an adult female is 0.4 to 0.5 cubic feet per hour, and by an adult male, 0.6 to 0.7 cubic feet per hour, the average for a mixed assemblage being about 0.6.

Dr. De Chaumont, a French chemist, made some tests along this line, and states that when the organic matter in the air begins to be appreciated (smelt) by the senses, and the air is said to be "rather close," there is present slightly more than four parts of carbonic impurity per 10,000 cubic feet of air. When the smell begins to be disagreeable, and the air within the room seems "close," the carbonic impurity is 6.5 parts in 10,000 cubic feet. When the smell is decidedly offensive and the air "very close," the carbonic impurity is about 12 parts in 10,000 cubic feet. We may add that the air at this time has reached the danger point in its impurity.

Methods of Ventilating

No building of any considerable size can be ventilated except by mechanical means, although a residence or small building may be provided with a ventilating chimney, which will answer every purpose. A galvanized iron or copper ventilator of the type commonly known as the "Globe," or those of similar construction, when placed on a one-story building, such as a chapel, school or the like, will allow abnoxious gases, smoke or steam from manufacturing to pass into the atmosphere, the currents of surrounding air, or the wind, producing a suction which exhausts the air from within the building. Many good ventilators of a similar character are manufactured and have proven practical.

A ventilating chimney when used in connection with a hot-air furnace will give the very best results. The requirements are that, in place of the ordinary brick flue, a large shaft or brick

shaft should be erected through the center of the house or building. Through the middle of this stack the smoke pipe is run, which, if the building be a low one, may be made of terra cotta pipe, tightly cemented at the joints. However, a wrought iron stack is preferred, which may be carried to any height desired.

Fig. 70 shows a plan of such a stack, in which *A* is the wrought iron stack, and *B* the smoke and ventilating space. Fig. 71 is a sectional view of such a stack as might be used in a two-story

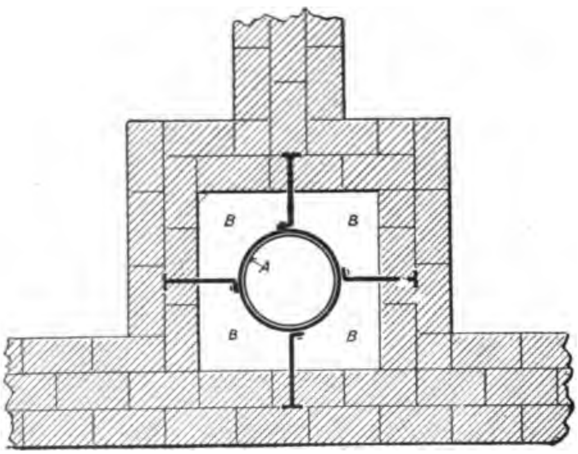


Fig. 70—Plan of Ventilating Stack.

building, and shows the stack resting on a cast iron bed plate supported by a brick pier. It should be properly stayed with iron braces, one for each eight or ten feet of height. A good style of such a brace is illustrated in the plan, Fig. 70. It is made of heavy wrought iron and consists of a ring surrounding the stack, to which are bolted four braces, the ends of which are split and turned in opposite directions for tying into the brickwork as the stack is being constructed. On the top of the shaft should be placed a heavy galvanized iron hood, supported by upright standards of iron 18 to 24 inches in length, as shown.

The wrought iron flue is placed in sections and riveted and braced as the stack is being built. This is also true of the frames for the foul-air registers or openings.

The heat from the smoke pipe or flue will expand the air in the ventilating shaft and cause an upward movement of the air, which will exhaust the foul air from each room connected to it.

A cold flue is of no use as a ventilating shaft, inasmuch as no means being provided for expanding the air and overcoming

the pressure of the atmosphere (14.7 pounds at sea level), the air in the flue remains "dead" or inactive, and it is absolutely

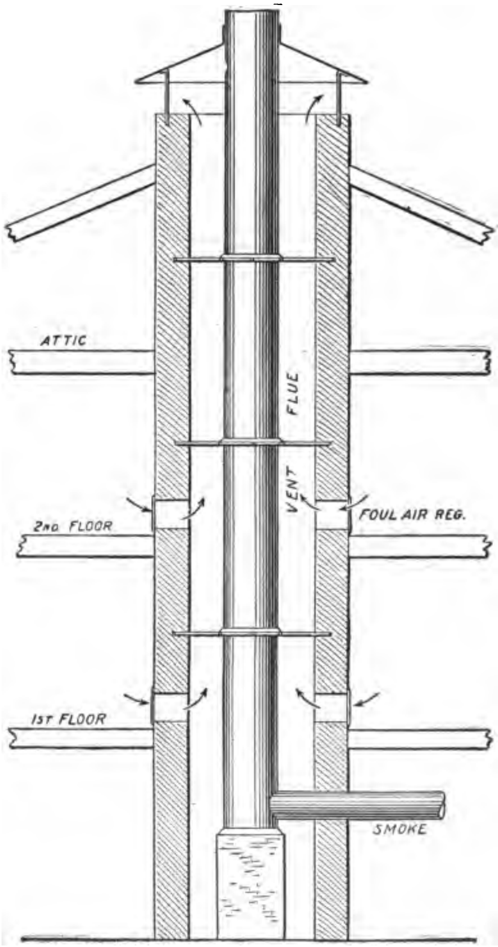


Fig. 71—Sectional View of Ventilating Stack.

necessary to overcome this pressure on the flue before an upward movement of the air in the shaft can take place.

CHAPTER XI

VENTILATION BY THE USE OF PROPELLER FAN

In the preceding chapter we discussed a method of ventilation that might be termed "natural ventilation." However, not all buildings are so constructed that a ventilating flue of the character mentioned therein can be erected except at such a considerable expense that the owner is loath to consider such a system. Since electricity has become so common for lighting purposes, and by reason of the fact that nearly every town has a separate electric plant, or contracts for electric current from some adjoining city, the matter of obtaining proper ventilation of our homes, or in other buildings, can easily be arranged for. By this statement we refer to the proper use of an electric propeller fan.

This covers a method which should be carefully studied by the furnace man. It is one so simple of adaptation, and yet so effective in operation, that it provides a long-felt want.

The electric current ordinarily used by an incandescent burner is sufficient to operate a fan which will thoroughly ventilate any residence of medium proportions and construction, and the expense of running the fan is so slight as to be scarcely worthy of mention, particularly when the results attained are regarded in their true light.

We have reference to the propeller type of fan as illustrated in Fig. 72. A fan of this character is designed to move air against a very slight resistance, the blades being curved, propelling the air forward by impact, and when installed in the attic of a building it exhausts to the atmosphere direct or through a short duct.

A system of ventilation of this kind consists of register faces or open panels placed in the baseboard of each room to be ventilated and connected to an upright tin or galvanized iron duct from each room, terminating in the attic of the building, which is used as a plenum chamber. An opening in one of the gable ends of the attic is made and framed to the size and diameter of the fan, the flange of which is bolted to this frame. An

attic window may be arranged for the purpose, the framework being built in such a manner that the window may be closed when fan is not in use. See Fig. 73.

The fan is now ready for the wiring to the motor. A rheostat or speed controller is attached in a convenient place on the first floor, by which the fan may be started, stopped or the speed of it controlled. These fans are made for two speeds, namely, medium and maximum. Medium speed fans vary according to size in the number of revolutions per minute, from 800 for the 18 inch to 200 for a fan 6 feet in diameter, and this type is recommended for ordinary ventilating work on account of being practically noiseless in operation.

Maximum speed fans vary from 1,000 revolutions for the 18 inch to 270 for a 6 foot fan.

The following table gives the size, revolutions per minute, horse power and cubic feet of air moved for medium speed fans from 18 to 72 inches in diameter:

Fig. 72—Propeller Fan.

Diameter of fan, inches.	Horse power.	Revolutions per minute.	Cubic feet of air delivered.
18	1/8	800	2,000
24	1/4	600	4,000
30	1/3	450	6,700
36	1/2	425	9,500
42	5/8	350	12,600
48	3/4	300	16,700
60	1 3/4	250	25,700
72	2 1/2	200	37,000

In handling or moving air by a fan the amount delivered

depends upon two factors, viz., size and speed. Further, if the air is forced through a duct or ducts, the element of friction, due to resistance encountered, must be considered.

There are some few rules which it will be well to remember:

1. The amount of air delivered by the fan varies directly as the speed of it. Doubling the number of revolutions doubles the volume of air delivered.

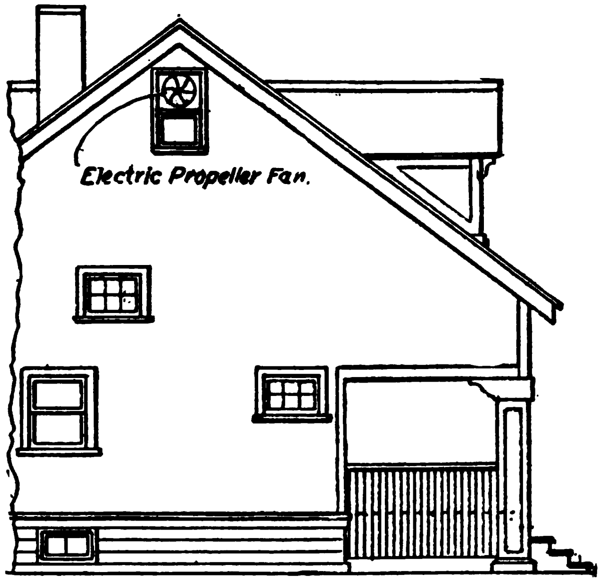


Fig. 73—Propeller Fan in Attic Window.

2. The air pressure varies as the square of the speed; for example, if the speed is doubled the pressure is increased four times. As we desire by the method described to deliver the air directly to the atmosphere, this rule need not be regarded as important for our purpose.

3. The power required is increased eight times when the speed is doubled. Thus it is more economical to use a large fan at a low speed than a small fan at a high speed to move the same volume of air.

4. The temperature of the air to be moved affects the pressure required and the power necessary. Increasing the temperature of the air reduces its weight and diminishes the power necessary to handle a given volume.

Let us consider, in ventilating an eight-room house, that there

are five rooms in which the air is to be completely changed four times hourly. These rooms average 15×20 feet and have 10-foot ceilings. $15 \times 20 \times 10 \times 5 = 15{,}000$ cubic feet of air to be moved, which, when multiplied by four, the number of air changes, equals 60,000 cubic feet to be moved hourly, or 1,000 cubic feet per minute. By reference to the table given above it will be seen that only a very small fan is necessary for this work.

The proper amount of pure fresh air must be admitted through the cold air duct and warmed by the furnace to such a degree that the various heat losses of the rooms are taken care of and a uniform desirable temperature is maintained.

Many heating contractors contend that, providing the impure, contaminated air is removed by an exhaust fan, the inward leakage around windows and doors is sufficient to supply all of the pure air necessary for the ordinary residence. This is not true, for, considering that this applied to the building noted above, it would be necessary for 200 cubic feet per minute to leak into each of the five rooms figured, and cold air admitted in such quantities would produce unpleasant drafts dangerous to the health of the occupants. One of the first considerations in the movement of air for ventilation is that there shall be no drafts experienced by the occupants of the room or building.

There is a great advantage in installing a fan of this character, viz., that proper ventilation may be provided during the warm weather period, when the heating apparatus is not in use. The effectiveness of any method is measured by the conditions of the weather. A heavy atmosphere or excessive velocities of the wind will have a much greater effect upon any system of natural ventilation than it will upon a positive mechanical system as above described.

Let all furnace men become acquainted with every phase of this all important subject. There is no doubt but that heating and ventilation are to be inseparably bound together, and we must look to our system of warming to assist us in our methods of ventilation. On the other hand, every furnace man of experience knows also that it is easier to warm a well-ventilated building than it is to heat one in which the air is foul or dead.

Efficiency of the Exhaust Fan

Exhaust fans are efficient for clearing factory rooms of smoke, poisonous gases or the fumes from chemicals used in manufacturing, and by the admission of a sufficient quantity of fresh air properly warmed it is possible to keep the rooms at a comfortable temperature and the air fresh and pure. Furnaces may be used in connection with exhaust fans for this purpose, and for

warming and ventilating small factories or other buildings a system of this kind is efficient and may be installed at low cost.

The fan may be driven by a motor, belt driven or direct connected, and as nearly all of the larger towns, as well as cities of any size, have an electric light and power plant, the power to operate the fan may be secured at a nominal cost, as an exhaust fan run at low speed requires but a small amount of power to drive it, owing to the fact that the air is usually moved against a very slight resistance.

In this connection we quote from an article by Wm. H. Hayes which was recently published in SHEET METAL. Mr. Hayes says:

"I am indebted to one of the largest and best known blower concerns for the capacity table printed in this article. This is presented for the reason that the power required to drive exhausters is an important factor when a deal is being negotiated in the piping business. Yet it is a factor very often regarded as one of small importance.

"By referring to this table the reader will see how increasing the speed of a fan by a few revolutions will more than double the amount of power required to drive it. Take, for example, the 40 inch exhauster fourth in the lower table; 4 horse power will drive it 1,090 revolutions per minute, yet to drive it 1,785 revolutions, an increase of speed of but 695 revolutions, requires 17.35 horse power. The reader will note also the last statement made underneath the table, viz.: 'If the suction area is less than the inlet of the fan, the power and volume will be reduced and the pressure increased.' Thus, if it is a question of power with the prospective purchaser, sell him a larger fan.

Speed, Capacity and Horse Power Required for Steel Plate Exhaust Fans

"I am indebted to the same concern for another table, given below, and which shows how speed can be cut down and power saved by adopting the suggestion.

"To quote the American Blower Company: 'Supposing we have 284 square inches of area in all the branch pipes and the main suction pipe after the last branch is taken in—19 inches in diameter. The various sizes of fans which can be applied, with their respective results, are shown in the table below, this being based on 100 feet of suction pipe, 100 feet of discharge pipe, four elbows in the pipe and a properly proportioned separator:

No. of fan	½ Oz. Pressure: Diam. of wheel, in..	½ Oz. Pressure: Width, periphery, inches	½ Oz. Pressure: Diam. inlet (inside) in.	¾ Oz. Pressure: R. P. M...	¾ Oz. Pressure: Cubic ft. per minute	¾ Oz. Pressure: Brake, horsepow'r	1 Oz. Pressure: R. P. M...	1 Oz. Pressure: Cubic ft. per minute	1 Oz. Pressure: Brake, horsepow'r	1½ Oz. Pressure: R. P. M...	1½ Oz. Pressure: Cubic ft. per minute	1½ Oz. Pressure: Brake, horsepow'r
25	16	6⅛	10	985	1,095	0.30	1,200	1,345	0.56	1.390	1,555	0.85
30	19	7⅛	12	830	1,580	0.43	1,012	1,940	0.80	1,170	2,240	1.22
35	22	8⅛	14	715	2,155	0.59	876	2,635	1.08	1,010	3,040	1.66
40	25	9⅜	16	630	2,820	0.77	772	3,450	1.41	890	3,980	2.17
45	28	10⅞	18	563	3,560	0.97	689	4,360	1.78	795	5,030	2.74
50	31	12⅜	20	508	4,400	1.20	622	5,390	2.20	719	6,220	3.39
55	34	13½	22	464	5,330	1.45	567	6,525	2.66	655	7,530	4.10
60	38	14½	24	415	6,350	1.73	509	7,775	3.18	587	8,960	4.89
70	44	15⅝	27	375	7,440	2.02	459	9,120	3.72	530	10,500	5.72
80	50	16½	29	328	10,050	2.75	402	12,100	4.94	464	13,980	7.62

No. of fan	1 Oz. Pressure: R. P. M...	1 Oz. Pressure: Cubic ft. per minute	1 Oz. Pressure: Brake, horsepow'r	2 Oz. Pressure: R. P. M...	2 Oz. Pressure: Cubic ft. per minute	2 Oz. Pressure: Brake, horsepow'r	3 Oz. Pressure: R. P. M...	3 Oz. Pressure: Cubic ft. per minute	3 Oz. Pressure: Brake, horsepow'r	4 Oz. Pressure: R. P. M...	4 Oz. Pressure: Cubic ft. per minute	4 Oz. Pressure: Brake, horsepow'r
25	1,710	1,910	1.56	1,966	2,200	2.40	2,420	2,690	4.40	2,780	3,100	6.78
30	1,436	2,750	2.25	1,655	3,175	3.46	2,035	3,875	6.32	2,345	4,475	9.77
35	1,240	3,730	3.06	1,430	4,310	4.70	1,755	5,260	8.60	2,025	6,085	13.26
40	1,090	4,880	4.00	1,260	5,640	6.15	1,545	6,885	11.22	1,785	7,955	17.35
45	976	6,180	5.06	1,125	7,140	7.79	1,380	8,710	14.36	1,590	10,050	21.90
50	882	7,640	6.25	1,015	8,820	9.63	1,247	10,740	17.50	1,440	12,420	27.10
55	805	9,250	7.58	927	10,650	11.60	1,138	13,000	21.20	1,310	15,050	32.80
60	720	11,000	9.20	830	12,700	13.85	1,020	15,500	25.25	1,175	17,900	39.04
70	650	12,900	10.57	750	14,875	16.20	920	18,150	29.60	1,060	21,000	45.80
80	569	17,170	14.05	656	19,800	21.60	805	24,200	39.50	930	28,000	61.00

Double fans have double the capacity given above, and require twice the power to drive at given speeds and pressures.

This table is based upon the inlet and discharge pipes being the same area as the fan inlet. If the suction area is less than the inlet of the fan, the volume and horse power will be reduced and the pressure increased.

Size of fan.	Speed.	Horse power.
45 inches	1,300 R. P. M.	11 2/3
50 inches	1,010 R. P. M.	8 3/4
55 inches	810 R. P. M.	7
60 inches	650 R. P. M.	5 2/3

"Thus it will be seen that to use a 60 inch fan instead of a 45 inch fan is to reduce the power more than one-half."

CHAPTER XII

HUMIDITY AND THE VALUE OF AIR MOISTENING

Up to the present time practically every furnace man seems to have had but one object in view when installing a hot-air furnace; namely, to install a furnace of such size and in such a manner that each dwelling or building may be satisfactorily warmed, notwithstanding the most adverse conditions of wind and weather prevailing. True, there are those in the trade who keep in touch with all the later improvements, who read and study the results of various experiments calculated to better the general conditions of warm-air heating—in other words, keeps up to date—but they are few in number.

Humidity and the value of air moistening cover a subject that should be carefully investigated and learned by all heating contractors. It is a subject easy to understand and, when properly understood, easy of application. Many articles of great value on this topic appear from time to time in the trade press, and the furnace man who gives them but scant or passing attention is missing instructive literature which will later prove of vast importance and necessity to him.

We know that the earth is surrounded by a belt of atmosphere several miles in thickness and that this air contains more or less vapor, the amount varying according to the temperature or its proximity to a body of water. Those of our readers who have lived in the vicinity of, or have visited the shore of any one of the Great Lakes, or even many of those inland bodies of water less extensive in area, may have noticed that, as a rule, they lie in a basin and are approached down a hill, which is sometimes very short and abrupt, and again at other times long or gradual in its descent. No matter which geographical condition exists, it is very apparent that the atmosphere after the crest of the hill is passed becomes very balmy, humid and of a satisfying nature, all of which is due to the proximity of the body of water. We may reach or obtain this same delightful condition and enjoy this same balmy atmosphere within our homes.

The writer believes that this subject is too little understood and is given too little attention by furnace men.

The great Architect of the Universe never intended that we should pass one-third or more of our lives shut up in almost air tight boxes; neither did he intend that we should be compelled to breathe tainted and poisoned air, yet this is what we are doing day after day with the result that as a nation we are heir to all sorts of diseases of the throat and lungs, tuberculosis, bronchitis, etc.

This condition and the effects of it will perhaps be better realized when we say that statistics show that over 30 per cent. of all deaths in this country are due to diseases of the throat and lungs, and today the treatment most generally prescribed by the physicians for such ailments is more fresh air, and by this advice is not meant the outside air, such as comes to us within our homes. baked by the average heating apparatus, but clean, pure, and humid air, such as an out-of-door climate provides.

There is no form of artificial warming apparatus by which this ideal condition may be produced and sustained so well as by a hot air warming system properly installed.

The average steam or hot water warming apparatus provides only for heat. The introduction of a supply of fresh air is generally overlooked entirely, or when introduced at all is only provided for in the homes of well-to-do people, who have ample means to pay the increased expense of installation and maintenance of such an apparatus.

As we have said before, it is by reason of the moisture in the air that it carries and retains heat, and the dryer the air, the more difficult it is to heat.

The air is capable of carrying a large amount of moisture. This may be noticed during a fog and again by the dew deposited during the night at certain seasons of the year. In tropical countries the dew deposited is frequently so heavy that the eaves drip water, and if this condition did not exist the tropics would not be habitable.

A year or two ago, when discussing the importance of air-moistening, the writer remarked somewhat as follows: "The process of refining or manufacturing raw material into a finished product has been carried on for many centuries. Had somebody stated to the architects of ancient Rome, or to the architects and constructors of our own national capitol, or of our more modern buildings, that in the twentieth century *we would be manufacturing climate,* they would all alike have disbelieved the statement, and considered that the speaker was bereft of reason." However, that is exactly what we are accomplishing

in hundreds of buildings today and it has come to be a very important factor of an up-to-date heating and ventilating apparatus, more particularly in our schools and public buildings. We can now provide an air supply for any building that will be free from soot and dust, that will be pure and also accompanied by a constant relative humidity, regardless of the condition of the outside air, or the location of the structure.

The principal installations of air-moistening apparatus have been placed in connection with the fan or blower system of heating. Very few have as yet been used with a warm-air furnace as the source of heat.

Let us consider briefly the term humidity with the fact that it is necessary that there be some moisture in the air we breathe. When the air is so laden with moisture that it is deposited in the form of dew, it has reached the point of complete saturation, or what is known as the "dew point." This deposit or dew is formed by the radiation or giving off of heat from trees, plants, etc., this action reducing the temperature of the surrounding air to the point of complete saturation, when the moisture will be deposited. We will consider that this point is one hundred per cent. In the most arid deserts there is some degree of moisture present in the air, probably thirty or thirty-five per cent. of complete saturation. In ordinary or temperate climates the prevailing percentage may be from fifty to seventy-five, the rate depending largely upon the temperature.

The dryer the air, the more difficult it is to heat. At high altitudes the atmosphere is dryer than that found at low points, hence it is cooler and more difficult to heat, as the cold air absorbs less moisture than the warm. On a hot summer's day, with the thermometer around 90 degrees Fahr., the air is capable of absorbing about fifteen grains of moisture for each cubic foot. At 32 degrees Fahr. (freezing), the air will absorb but little more than two grains per cubic foot. It is apparent then that by reason of the moisture present, the air carries and retains heat. The heating apparatus which employs an air-moistener to properly saturate or humidify the air is not only providing a healthful climate within the building, but is accomplishing it at less cost for maintenance than would otherwise be possible.

Reduction of Fuel

Exhaustive tests have demonstrated the fact that the saving in fuel effected by adopting proper methods of air moistening will pay the cost of such effort to say nothing of the increased comfort and healthfulness secured and probable saving in the expense of physicians' services.

Results of Investigation

One physician says: "Investigations have proven that the higher the degree of temperature, which increases the capacity for water, the greater will be the weight of a cubic foot of saturated aqueous vapor; therefore, by the addition of heat to the colder outside atmosphere entering the building, there must be an additional amount of vapor added to overcome the deficiency existing between the weight of a cubic foot of saturated aqueous vapor as received from the furnace from the outside, and the weight of a cubic foot of saturated aqueous vapor raised, by the addition of heat units, to the higher indoor temperature to produce a normal condition of the latter."

So much regarding the need of proper humidity. Now, let us for a moment consider the effect of it in connection with the proper warming of a house or other building.

We have said, and our readers have no doubt frequently read the statement, that a room heated to 60 degrees F., with a humidity of 55 per cent., is much more comfortable than a room heated to 75 degrees with a lower percentage of humidity. The climate, and when warmed to 60 degrees F. a building is comfortably heated. In this country we all know that a temperature of 70 degrees F. is the standard for living rooms, offices, or other rooms where the occupants are inactive.

The average warmed building, having no ventilation, is as dry as the desert of Sahara, and many eminent physicians have called attention to the bad results arising from it. The irritation of the mucous membrane of the throat and lungs, causing bronchitis and catarrh, is one of the worst evils consequent upon this condition of the air.

If in cold weather we are using outside air to supply the furnace, and this outside air is at 65 per cent. (as we measure humidity), we reduce the moisture to probably 30 or 35 per cent. in warming our rooms to 70 degrees Fahr. In continuing to pour warm air into the rooms under these conditions the radiated heat seems to penetrate through the air within, but without warming it. If we devise and employ some method of moistening it, the moist, humid air will hold and absorb the radiated heat and give it off to all cooler bodies within the room.

Humidity has been aptly called "Nature's great bed-blanket for all her children," and without it they would perish. Dry air extracts the moisture from the body, and it is accordingly necessary to warm the rooms to a greater degree in order to feel comfortable.

If our readers will note the difference between the English climate and that of America, a very good illustration of these

facts is apparent. The Englishman complains of the American winter climate because our homes, which to us are only comfortably warmed, are to him overheated. The American finds the reverse to be the case when visiting England, and complains of the cold. The human body can be likened to a furnace and the heat developed within it must be given off as rapidly as it is produced if we are to remain healthy. This dissemination is accomplished largely by perspiration. The Englishman is accus-

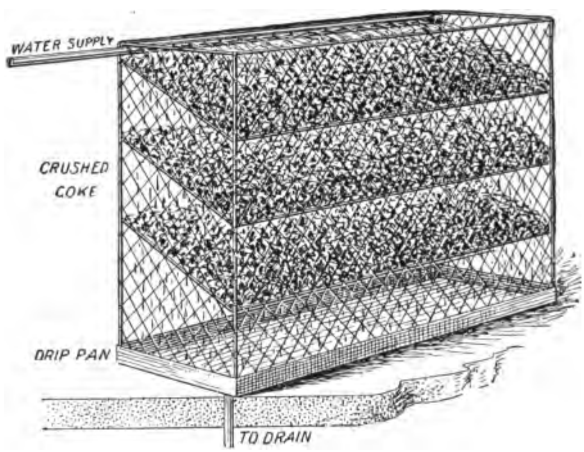


Fig. 74—Galvanized Iron and Wire Air Moistener.

tomed to a low rate of perspiration, the American to a higher rate, the difference being due to the fact that each has grown up in or become susceptible to a different climate.

Now, regarding the probable saving in fuel by changing these conditions, it is competently estimated that 25 per cent. of the cost of heating is expended in raising the temperature within our homes from 60 to 70 degrees. This being established it follows that one-fourth of the cost of fuel can be saved by maintaining the temperature of the rooms at 60 degrees and providing for the loss in moisture (humidity) due to heating the air; in other words, by keeping the percentage of humidity at 65 or 75. The result will be a sensible temperature within the rooms which, if no thermometer is at hand to consult, will seem, and in fact is, entirely comfortable.

How may we provide for properly moistening the air? This question naturally follows in our discussion of the subject.

There are several methods by which the air supply of a warm-air or furnace-heating system may be moistened and made humid. The common practice of placing a small cast iron receptacle in

the side of a furnace casing, called a "water-pan," "vapor-pan," etc., is but a feeble effort in this direction, and it does not amount to anything for the purpose intended. True, the water in this pan evaporates into the air supply of the furnace, but it is very much the same as would be the effort of the arid dry air of a desert to take its moisture from a small brook.

The cold air may be admitted through a chamber in which are a number of compartments filled with crushed coke, over which small streams of water from a perforated water pipe trickle down, keeping the coke wet. A drip-pan at the bottom may connect with an overflow pipe leading to a drain.

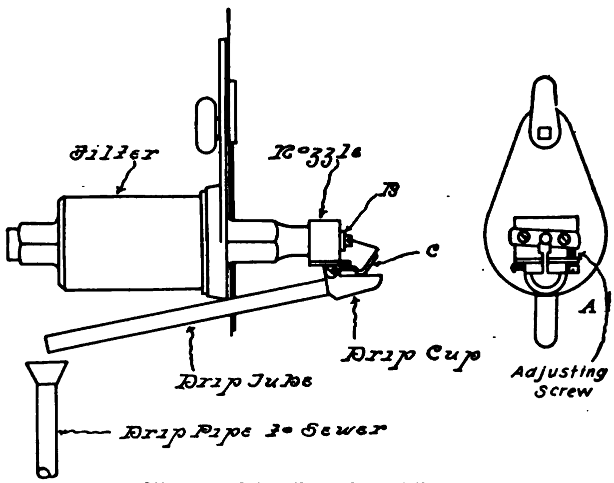


Fig. 75—The Herr Humidizer.

Fig. 74 illustrates this method, the coke being broken into small pieces and held in a galvanized iron and wire rack inside the boxing at the cold-air inlet.

Another method is the spraying of the air by means of one or more small atomizers or sprays playing on the incoming air.

There is but little difference as to whether the air is moistened before or after it is heated, except that moist, humid air absorbs the radiated heat better than the dry air. Spray nozzles of brass may be obtained and they are of simple construction. The centrifugal action prevents the openings from clogging. For a job of any considerable size or importance a bricked-in humidifying chamber with cemented floor properly drained may be provided in the basement and water pipes with sprays be placed in this chamber.

An apparatus for spraying the air, after it has been heated,

known as the Herr Humidifier, has been found to be very effective and is strongly recommended by those who have tried it. This device seems to us to be worthy of careful investigation on the part of the furnace man. It has been greatly improved and some few defects in the original apparatus have been corrected.

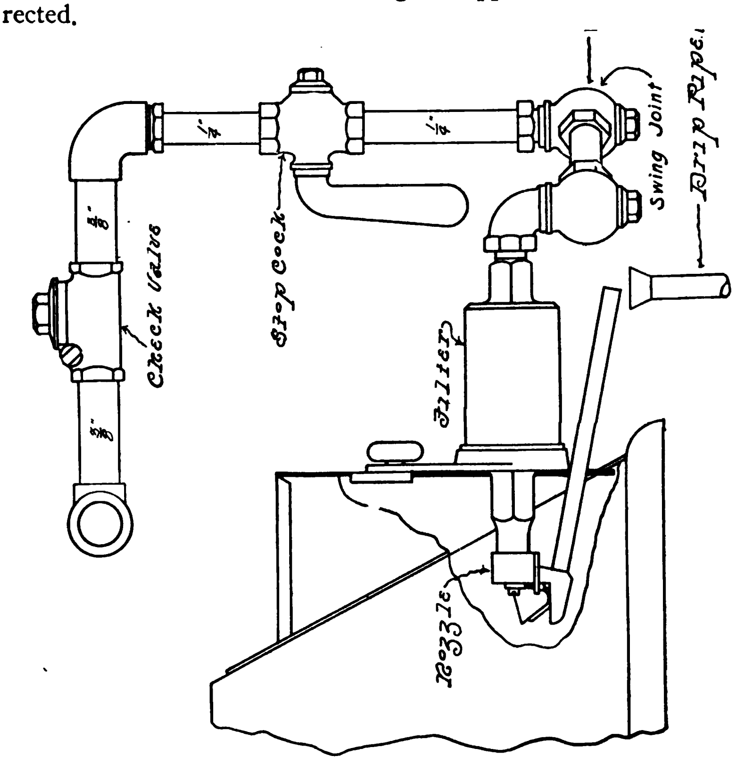


Fig. 76—Humidizer Attached to Furnace Casing.

Fig. 75 shows a view of the humidizer proper—the spray nozzle and adjustments. The small stream of water passing through the apparatus strikes the spoon C and is deflected in the form of a fine spray, which saturates the air in the top casing of the furnace. The size of this stream of water, and consequently the amount of moisture mixed with the air, is regulated by the adjusting bar B.

Fig. 76 shows the method of attaching the humidizer to the casing top of the furnace, and Fig. 77 shows a complete installation of the same, with an apron provided to utilize the drip from the spray nozzle.

We believe that no further description of the device is neces-

sary, and that the utility of it will be apparent to every practical furnace man.

The hot air as it rises to the top of the casing is moistened by the fine spray of water, which is absorbed, and then passes through the leader pipes to the rooms above, producing balmy,

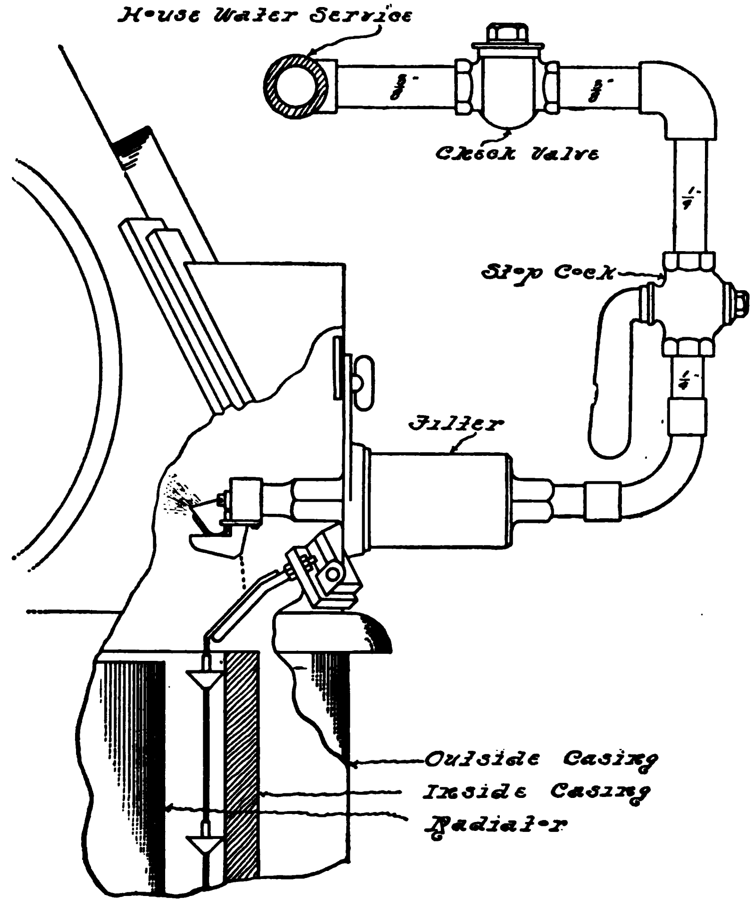


Fig. 77—Complete Installation of Humidizer.

natural atmosphere. Tests have shown a relative humidity of from 60 to 65 per cent. of complete saturation.

Placing the Water Pan

The feeble effort to obtain these results by using a water pan

in connection with the furnace, we all no doubt are familiar with. The pan is located at the wrong point to be effective, even to a small degree. The water should be above the source of heat.

A much more effective water pan may be made by riveting and soldering a strip of galvanized iron around

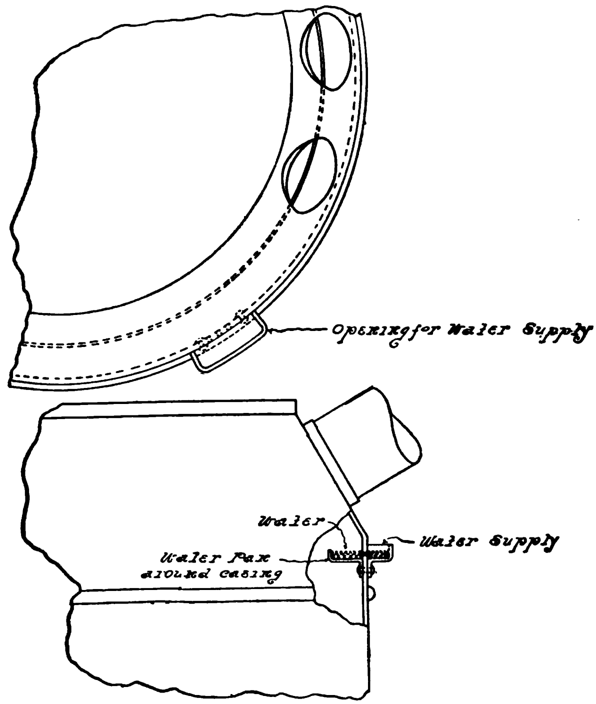


Fig. 78—Sectional Elevation and Plans Showing Proper Location of Water Pan.

the inside of the top casing, immediately under the openings for the connection of hot air leader pipes. This ring should be from two to two and one half inches wide with the inside edge turned up a little over one-half of an inch. In Fig. 78 the sectional elevation illustrates the idea and the plan above shows a little cup riveted on the side of the casing as a device for filling small holes in the casing connecting with the pan on the inside of the casing.

The Hygrometer

To properly understand the relation of humidity to heating we must know that the sensible temperature (that is, the temper-

ature felt by the body) corresponds to the temperature of the wet bulb thermometer; therefore, the dryer the air, the greater is the difference between the actual and the sensible temperatures.

We measure or determine the temperature and humidity of the air with an instrument known as a hygrometer or hygro-

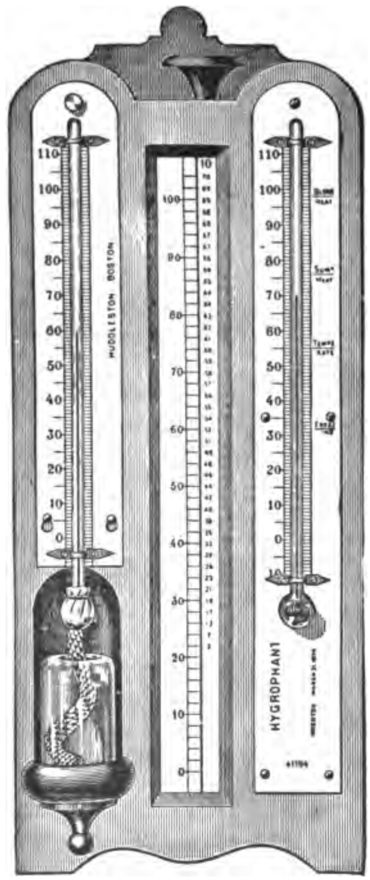


Fig. 79—The Hygrometer.

phant. On this instrument two standard thermometers are provided, one (a dry bulb) showing the temperature of the air, and the other (a wet bulb) showing the temperature due to evaporation (Fig. 79). In the center is a fixed scale, and to the right of this is mounted a cylinder upon which is inscribed columns

of figures with headings numbered from "1" to "22." This cylinder may be freely turned by the knob shown at the top of the instrument, and the figures appearing at the top of the column represent the difference in the reading of the dry and the wet bulb thermometers. Revolve the cylinder until this number appears at the top and note the number opposite the figure on the fixed scale representing the reading of the dry bulb thermometer. This number gives the percentage of humidity.

For example (note illustration), the dry bulb thermometer shows 70 degrees and the wet bulb 60 degrees. 70 — 60 = 10 number at the top of the cylinder which has been revolved until this number appears.) Now note the cylinder number opposite the figure 70 on the fixed scale. It is 56, which is the relative humidity or percentage of moisture in the air, according to the thermometer readings. This is a most interesting as well as instructive instrument.

CHAPTER XIII

RECIRCULATION OF AIR IN FURNACE HEATING

It is generally recognized that many of the objections to furnace heating are brought about by reason of the installation of cheap, unsatisfactory, and unsanitary work, or through the ignorance displayed by the unskilled man in laying out and installing the job.

We will consider some of these objections, their cause and how they can be remedied and the work made satisfactory. Probably the first and most frequent objection heard is that made to the condition of the air within a building when it is warmed by a hot air apparatus, viz., that it is overheated and "stuffy." The frequency of this fault we must admit; and it is brought about through the installation of too small a furnace and the provision of too small an area for the cold or fresh air duct. A further source of complaint is found in the quality of the air supplied.

Quality of Air

Let us consider for a moment this complaint and the cause of it. If a certain size of a building requires the consumption of 12 pounds of coal per hour to transmit the necessary number of heat units to take care of the exposure or cooling surfaces, a certain size of grate will be required to properly burn this amount of fuel, and, in its turn, the heating surfaces of the furnace which transmit these heat units to the air passing through it, must be of a certain area if these surfaces are not to be overheated in the effort of transmission. This means, for example, that should 12 pounds of coal per hour be burned on a grate having three (3) sq. ft. of area, the rate combustion would be 4 pounds of fuel per sq. ft. of grate per hour. Assuming that from each pound of fuel, 8,000 heat units are available for warming purposes, then $8{,}000 \times 12 = 96{,}000$ units per hour will result from 12 pounds of fuel burned on 432 sq. in. of grate.

Supposing that a furnace having but 288 sq. in. or 2 sq. ft. of grate area was installed to warm this building, the attempt to

burn the fuel required on the reduced grate area requires so high a rate of combustion that the air passing through the furnace is overheated, thereby destroying its invigorating qualities, and making it unfit to breathe and "stuffy" in effect.

Air Outlet Necessary

Another reason for this condition (stuffy atmosphere) is due to the fact that many furnace men are trying to introduce warm

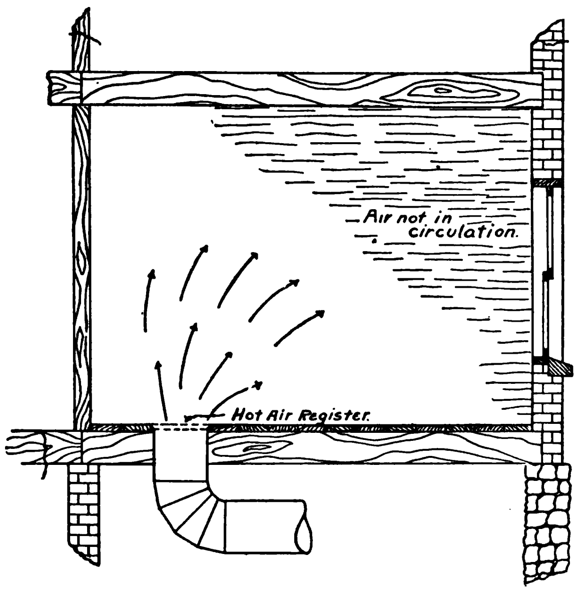


Fig. 80—Poor Air Circulation when Room has No Outlet.

air into a room which has no air outlet, except the leakage around windows and doors, doubtless overlooking the fact that only as much air can be admitted to a room as the amount which passes out, and the effort to heat the room in this manner makes necessary such an increase in the temperature and velocity of the incoming air as will drive it into the rooms.

Heating Windward Side

Right along this line is the complaint that during the prevalence of high winds it is impossible to heat the rooms on the windward side of the house. This complaint, as well as the preceding one, can be overcome wholly or in large part by the proper recirculation of the air within the building. Fig. 80 represents a closed

room without air outlets, except the leakage through walls and around windows. Note the manner of the circulation of the air, or rather the fact that there is practically no circulation of it. Place a rotating register and flue as indicated by Fig. 81 and note the difference in the movement of the air.

Supposing the room is on the side of the house most exposed to the strong winds of winter; the placing of a rotating register and flue along the outside wall of the room will do much to improve the circulation of the air in it, and consequently the proper warming of the room. Fig. 82 illustrates this condition.

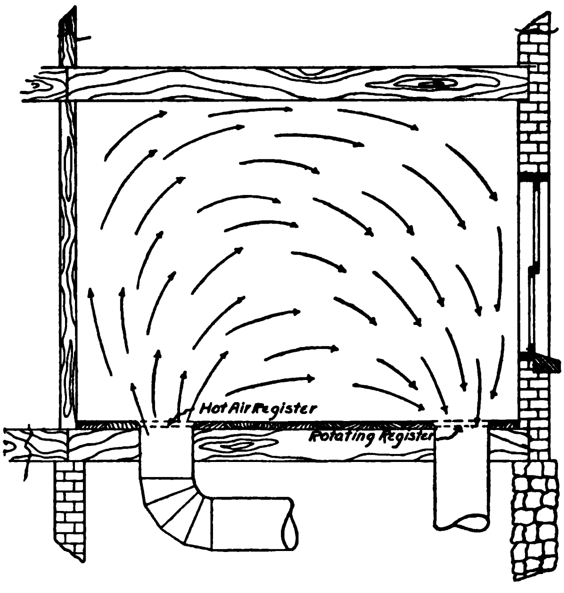


Fig. 81—Perfect Circulation of Air when Rotating Register and Return Air Flue are Employed.

In illustrating our discussion of furnace heating, we have for convenience frequently shown floor registers. We do not like floor registers. From a healthful standpoint they are bad, as they collect dirt and organic matter, and often much of the bad air in a room may be traced to the filth and dirt which has collected in the boxing under a floor register. If circumstances make necessary the use of floor registers, the face should be lifted out and the boxes wiped out at least monthly with some germ destroying wash.

Opposition to the Method

As stated in a recent chapter, there are some people identified

with furnace manufacture and installation who advise against the recirculation or rotation of the air within a building. These advocate a positive method of ventilation notwithstanding the consequent expense to be incurred in bringing about this desired condition.

The objection to the recirculation of the inside air seems to be based entirely upon the feeling that the quality of the air is lowered and that the health of the occupants thereby is endangered.

We believe that the filtration of air through outside walls and windows, considered with the fact that ordinarily less than half a dozen people inhabit a single dwelling, renders the contamination of the air to the point of stuffiness next to impossible.

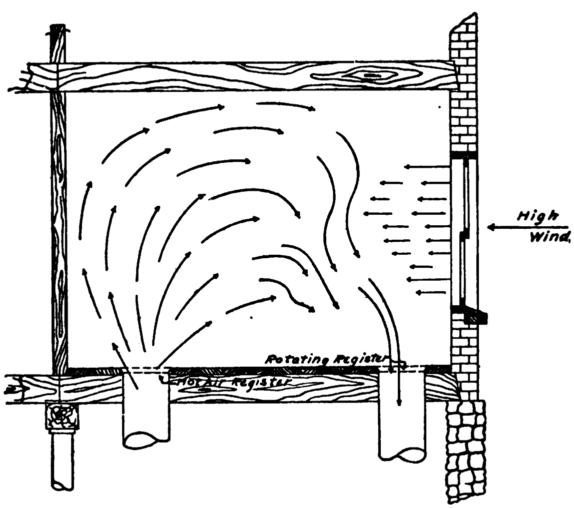


Fig. 82—Showing Effect of High Wind Against a Building Heated with Hot Air.

On occasions when a social function is given and a considerable number of people are present, the return air registers can be closed and the outside air used exclusively. This is also true in the event of any of the occupants being sick or affected with a contagious disease.

While we recommend ventilation—and plenty of it—the fact remains that a very great number of furnace heating plants are installed without any form of ventilation, and the amount of fresh air admitted is limited because of conditions stated in this article. The installation of return air ducts with rotating registers in the principal rooms, will aid in the distribution of the fresh

air admitted through the cold air duct, and this feature will not only make the furnace heat more positively, but will distribute the air at the least possible expense for fuel.

Obtaining Best Results

The furnace by itself cannot warm the building. It can do nothing more than warm the air, and it is up to the furnace man to take this warm air and provide methods for its carriage and distribution.

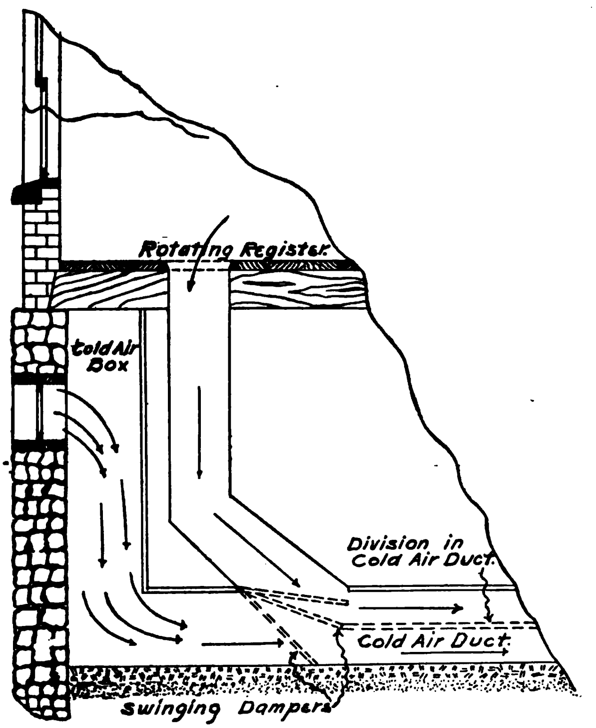


Fig. 83—Proper Construction of Return, or Recirculated Air.

The failure to obtain proper results when the recirculation feature has been introduced in furnace heating, is usually found to result from the fact that poor judgment has been exercised by the furnace man who has not fully understood the method to be followed.

Connecting Duct

Ordinarily the circulating duct should not be connected to the casing, or to the cold air pit of the furnace, but rather to the

cold air duct; and dampers should be arranged in such a manner that return air or fresh air may be used at will. The cord or chains operating these dampers may extend to a convenient place on the first floor. Fig. 83 shows the method of connecting the duct.

We recommend to the furnace man that he study the methods of return air circulation, and the advantages to be gained from the installation of such a system when properly erected.

CHAPTER XIV

AUXILIARY HEATING FROM FURNACES

When warming a building with a hot air furnace it frequently happens that there are some rooms or portions of the building which, owing to structural conditions or remote location, cannot well be warmed in the regular manner with hot air.

These conditions, which would interfere with the running of hot air pipes, will not interfere with the installation of hot water piping, and therefore several methods have been devised of combining a hot air and hot water heating apparatus, making use of but one fire for supplying the necessary heat for both systems.

This is accomplished by installing a somewhat larger furnace than would be required for hot air alone, and by placing a coil of pipe in the fire pot of the furnace or suspending above the fire a hollow casting, called an auxiliary heater, through which the water may circulate and receive the heat. The hot water circulating through the coil or casting is distributed through piping to one or more radiators located within the rooms to be warmed.

It is not necessary for the furnace man to be adept—that is, thoroughly versed—in the practice of steam fitting in order to successfully install combination jobs of this character.

Computing Size of Radiator

Probably the first knowledge that should be acquired pertaining to this method is to learn how to compute the size of radiator necessary to warm a room. This is determined by considering the cooling surfaces of the room, glass and exposed wall, much the same as for hot air heating. The following simple rule will give fairly accurate results:

First—Ascertain the square feet of glass surface (windows and outside doors).

Second—Ascertain the square feet of exposed wall surafce (outside walls, windows not deducted).

Third—Ascertain the cubical contents of the room to be warmed.

Divide the glass surface by 2.

Divide the exposed wall surface by 20.

Divide the cubical contents by 200.

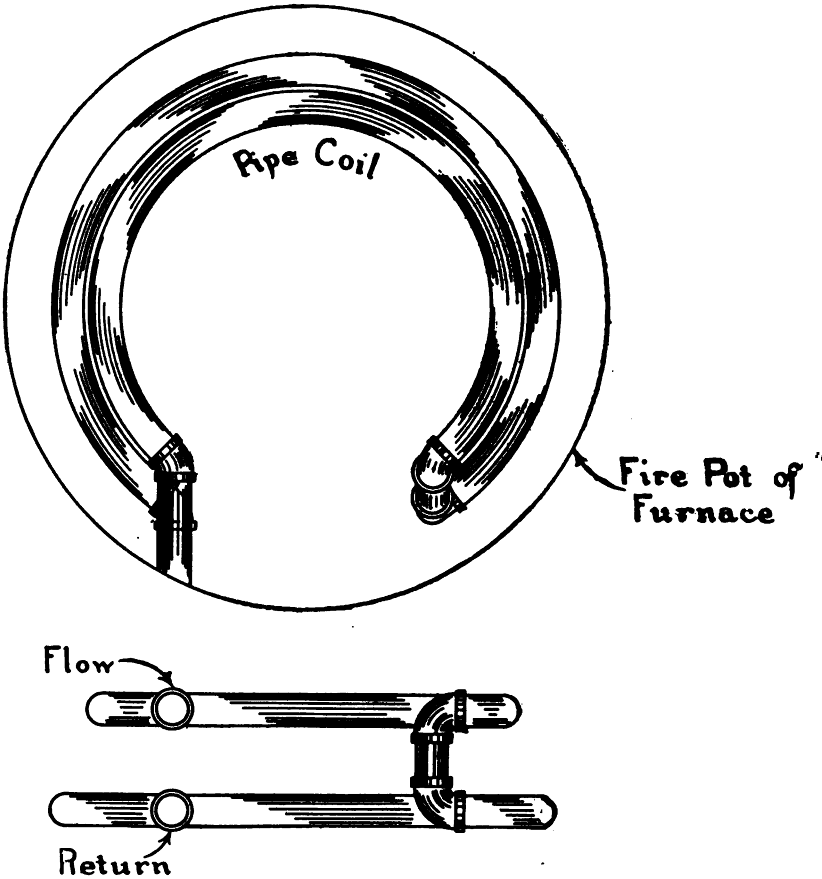


Fig. 84—Plan and Elevation of Pipe Coil.

The product of these results plus 60 per cent., will give the amount of hot water radiation necessary to warm the room to 70 degrees in zero weather with the water at a temperature of 180 degrees Fahr.

If the furnace contractor is in the habit of estimating according to loss per hour of heat units, he may determine the total

loss for the room in heat units and divide this sum by 150; this calculation will give the square feet of radiation required.

Heating Furnace Required

The next item to consider is the amount of heating surface to be provided in the furnace to supply the radiation required. This heating surface may take the form of a pipe coil as illustrated by Fig. 84, which shows a plan and elevation of a pipe coil, or

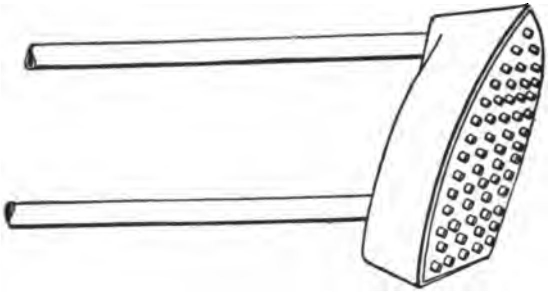


Fig. 85—Cast Iron Auxiliary Heater.

of a hollow casting as illustrated by Figs. 85 and 86. These cast iron auxiliary heaters are made in a variety of shapes and sizes. Each square foot of surface in the pipe coil shown by Fig. 84 if placed low in the fire pot, so that the hot fire comes in contact with it, will supply 50 sq. ft. of radiation with hot water at 180 degrees or 60 sq. ft. of radiation with the water at 160 degrees

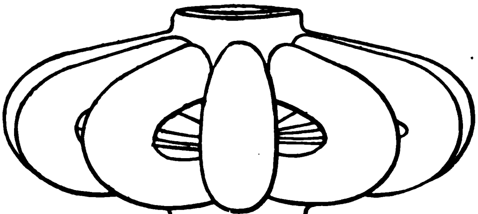


Fig. 86—Another Form of Cast Iron Auxiliary Heater.

at the radiator. If the coil is suspended above the fire it will supply from 25 to 30 sq. ft. of radiation.

Should a hollow casting similar to that illustrated by Figs. 85 or 86 be employed as heating surface in the furnace, it is suspended above the fire and varies in efficiency from 20 sq. ft. of radiation supplied for each square foot of heating surface in

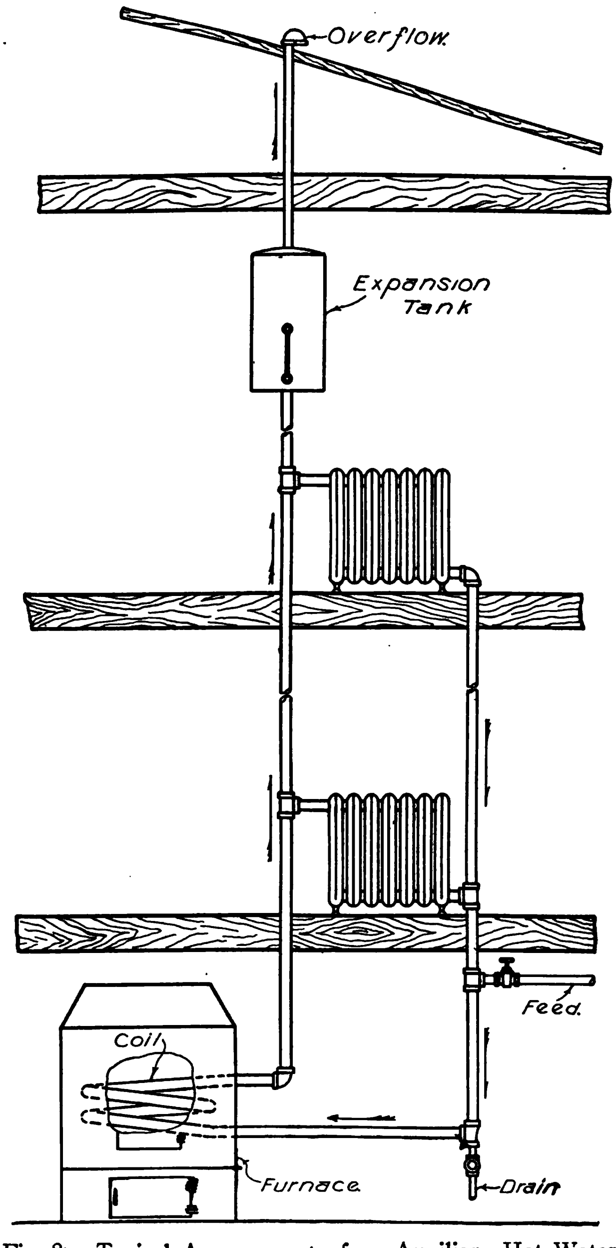


Fig. 87—Typical Arrangement of an Auxiliary Hot Water Heating Apparatus.

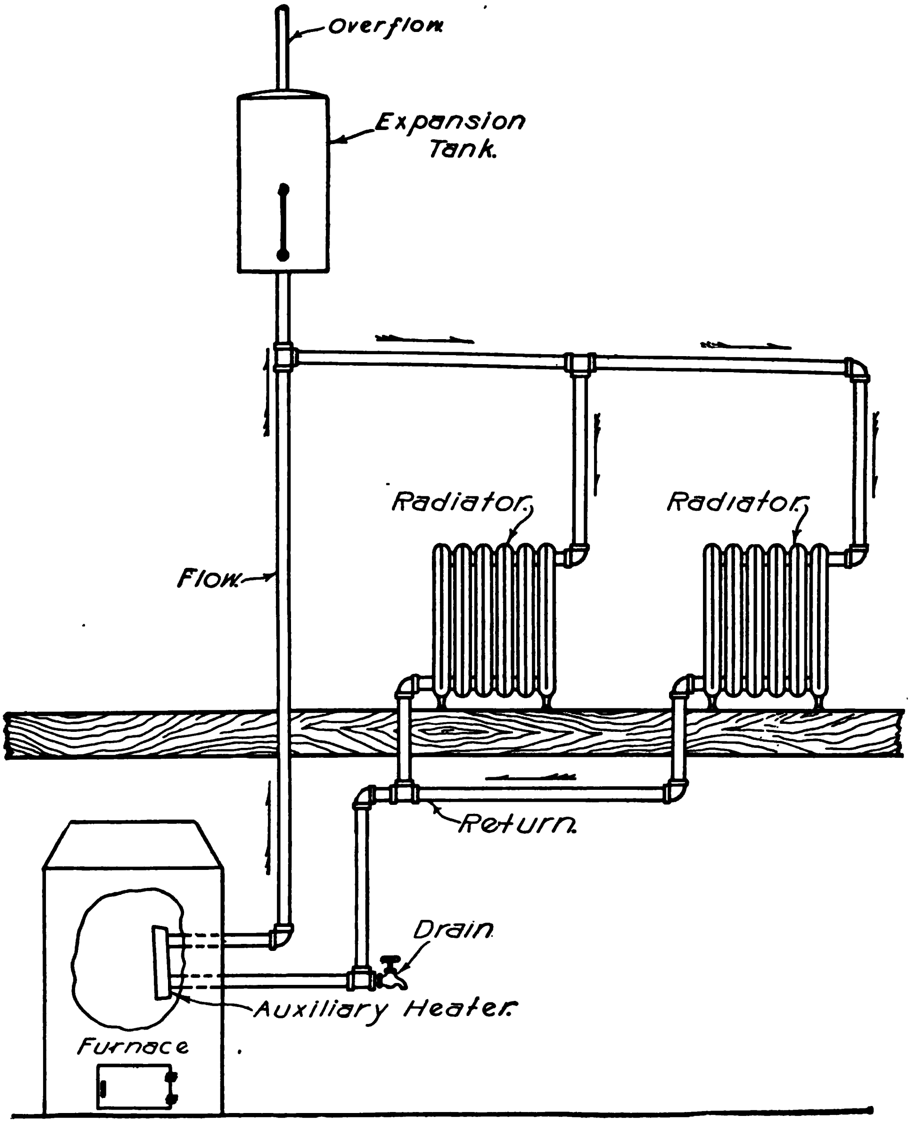


Fig. 88—Domestic Hot Water Supply from Furnace.

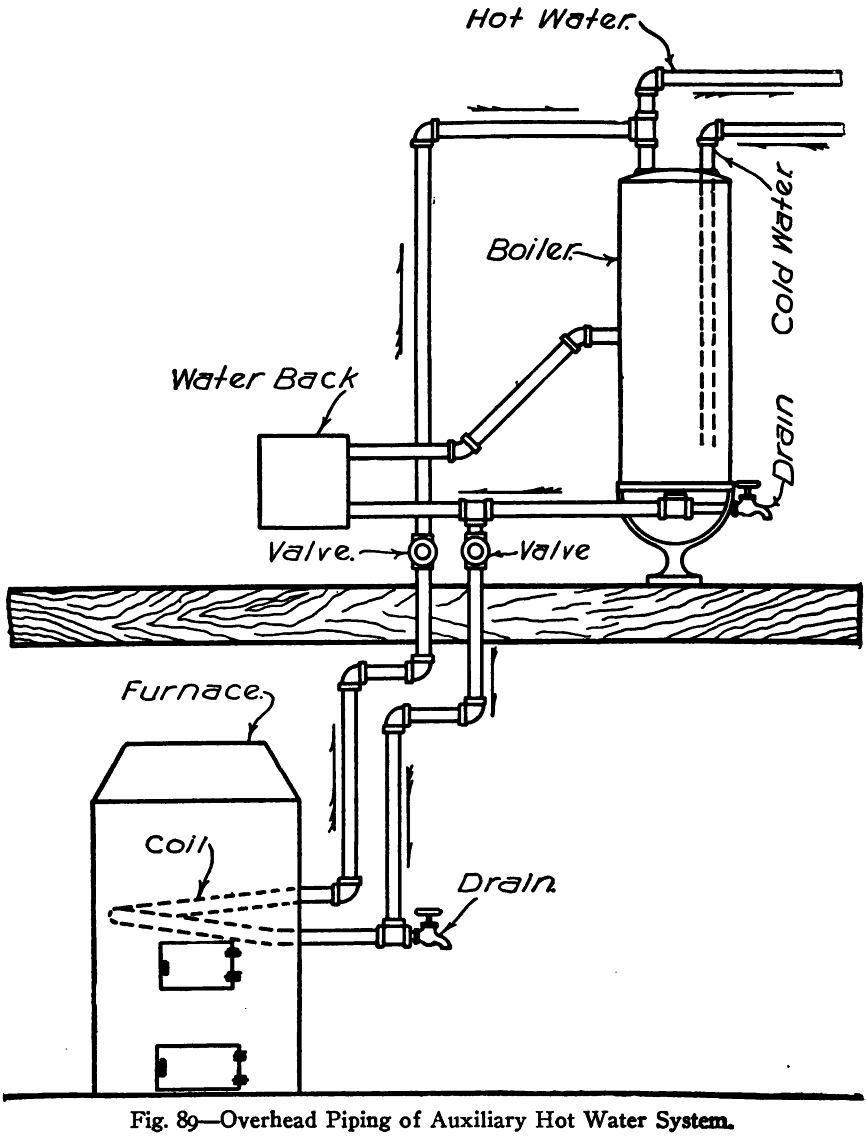


Fig. 89—Overhead Piping of Auxiliary Hot Water System.

the casting, to possibly 25 or 30 sq. ft., depending upon how much of the casting is direct heating surface and how far above the fire it may be located.

Installing the Apparatus

The method of installing the piping and of connecting to the radiators has more to do with the success or failure of a job of this character than the construction of any other part of the system. Fig. 87 is a typical illustration of an auxiliary hot water heating apparatus and shows two radiators supplied by a coil in the furnace.

Note the small tank at the top of the system. This is called an expansion tank. Water when heated from 32 to 212 degrees (the boiling point) expands 1/25 of its volumne, and unless some provision were made for taking care of this expansion the system would overflow when heated, and when the water in the system was again cooled and contracted, the upper part of the system would fill with air which would interfere with the circulation. The tank should be located in such a position that the bottom of it is well above the top of the highest radiator and the pipe connecting the tank with the system (called the expansion line) should be connected as indicated on the illustration. Ordinarily an expansion tank of from eight to twelve gallons' capacity is sufficient for a combination job. An eight gallon tank will take care of 200 to 250 square feet of radiation and a twelve gallon tank, 300 to 400 square feet.

The size of pipe to be used in connecting to the radiators is determined by the size of each radiator.

A 1 inch pipe will supply 35 or 40 square feet of radiation on the first floor above the furnace or 60 to 70 square feet on the second or third floor. In like manner a 1¼ inch pipe will supply 60 to 70 square feet on the first floor, or 90 to 110 square feet on the second or third floor. A 1½ inch pipe will supply 100 to 110 square feet on the first floor or 150 to 160 square feet on the second or third floor, and the main flow pipe from the furnace must have an area equal to the combined area of all radiator connections.

An installation of this kind is known as a circulating job, and no radiators or pipes are valved. The radiators are employed in exactly the same manner as would be a storage tank for domestic hot water use. If the radiators were valved and the valves should be closed, the excess of heating surface would boil the water in the system. The cooling surface of the radiators prevents this happening when they are in service.

Another method of installing an auxiliary hot water apparatus is illustrated by Fig 88, which shows a cast iron auxiliary heater

employed within the furnace. The piping system shown in the illustration indicates another of the several methods that may be used. The expansion tank is connected from the high point of the system, and therefore air valves on the radiators are not required, as all air in the system passes to the atmosphere through the expansion tank.

It is well that the furnace man should become acquainted with the methods of estimating and installing auxiliary heating systems, as they are frequently desired by the house owner.

Auxiliary heaters are frequently employed for furnishing hot water for domestic use and are installed in connection with the kitchen boiler or storage tank.

The piping is usually cross-connected with that from the kitchen range and valved so that the auxiliary heater may be cut out during the summer season when the furnace is not in use. Fig. 89 illustrates an installation of this kind.

An expansion tank is not required on a system of this kind, as the water is used under pressure, and a job of this character would be designated as a pressure system.

The heating surface required in the furnace auxiliary heater is 1 square foot for each 20 gallons of water in the storage tank or kitchen boiler.

CHAPTER XV

TEMPERATURE REGULATION AND FUEL SAVING DEVICES

The value of a good temperature regulator seems to be neither understood nor appreciated by the heating contractor.

What the governor is to an engine the thermostat is to a furnace. The governor, attached to an engine, prevents the engine from "running away" or speeding when the load or work it is doing is suddenly lightened,—in other words, it regulates the speed of the engine automatically, preventing useless waste and possible danger.

The thermostat or temperature regulator, attached to a furnace, prevents the overheating of the building and consequent waste of fuel. It also prevents possible damage due to overheating the furnace.

There are some features of temperature regulation which, if brought to the attention of the house owner in a convincing manner, should effect a ready sale of an appliance of this nature, as little necessity exists for argument on the part of the furnace man when such features are made known.

We have mentioned the saving in fuel, which may be effected by a system of thermostatic control. The health of the occupants of the home, and the comfort experienced, may also be considered as desirable features of temperature regulations.

A brief argument in favor of the thermostat may be made by considering these three features:

(a) Saving in fuel and consequent low cost of maintenance.

(b) Healthfulness due to uniformity of temperature.

(c) Personal comfort as a result of having a watchman (thermostat) in charge of the furnace, to open or close the draught doors at the required moment.

Briefly stated, the work to be performed by the furnace may be considered as follows:

Consulting a table of temperatures compiled by the United States Government, giving maximum and minimum temperatures of some thirty cities, and covering all sections of this country and Canada where heat is required in winter, we find that the average number of degrees the temperature is to be raised artificially is 80°. In Charleston, S. C., it is 47°, while in Duluth, Minn., it is 108°.

The average winter temperature for the period we call "the heating year" is a little under 40° F. As we have already remarked, in this country we demand a temperature of 70° within our homes, and therefore we must raise the temperature approximately, an average of 30°. It requires just so much heat, or the expenditure of just so many heat units to produce this result, and for every degree above 70°, shown by the thermometer, there is a loss of fuel in a direct ratio to the increase in temperature, and this loss at a low estimate is 25 per cent.

Of the healthfulness due to a uniform temperature, it seems necessary only to state that all physicians and scientists, who have made a careful study of the subject, report and agree, that next to the proper ventilation of our homes, a uniform degree of heat is essential to the good health of the occupants. We are safe in saying that few colds, and few of the more serious diseases so prevalent in winter, will be experienced, if a uniform temperature is maintained in the home.

Finally comes the question of personal comfort. It has been stated that this is the age of personal comfort, "the automatic age" and "the electrical age." It is now that the furnace man may deliver the solar plexus blow—the final argument.

The period when artificial heat is necessary comes as regularly as the time when food is necessary to sustain us, and the personal comfort, due to the work of the thermostatic watchman in attending the furnace, cannot well be calculated.

We may repeat what we had occasion some time ago to remark regarding the thermostat. "It is a boon to the busy man and a delight to the lazy man, and is more than self-sustaining, paying for itself in a season or two, after which it earns money for the owner at a rate never excelled by the best savings institution."

Arguments and facts such as these, when brought to the attention of the users of hot air furnaces, should make possible the sale of a good many thermostats, and materially add to the business of the furnace dealer.

Fuel Saving Appliances

Each pound of anthracite coal when used for fuel in a furnace gives off approximately 14,500 heat units. About 10,000 of these are available for heating purposes, the remainder being utilized principally in warming the air in the chimney flue to produce sufficient draft to carry off the smoke and products of combustion.

In considering the question of economy in fuel we may say first of all that it is a poor policy to select a furnace with a grate so small that it is necessary to keep the fire in a continual state of activity to properly heat the building. The frequent "stirring up" of the fire by a shaking of the grate and the addition of more fuel are as wasteful as they are unnecessary. With a furnace having a grate of adequate size, or perhaps a little larger than is absolutely essential, the very best result is obtained in the way of economy, provided the heater is fired in an intelligent manner. There is great waste in intermittent firing. By this we mean the opening of the draft door of the furnace, forcing the fire to greater activity and allowing the building to become overheated, requiring the opening of the windows. The coal should be permitted to burn just enough to give off the required heat units to keep the building warmed to the desired temperature.

This can be accomplished only by the use of some good system of temperature regulation which will automatically control the fire by opening and closing the draft and check dampers of the heater. The appliances to perform this work are called "regulators" or "thermostats," and there are many good and reliable kinds to be had.

It will be impossible here to illustrate and describe all of the various makes, and therefore we shall select several of those most commonly used, showing the manner by which they accomplish the service demanded of them and for which they are intended. It will be of interest to our readers to know somewhat of the history of temperature regulation, or of the invention and application of methods for automatically controlling the drafts of a heating apparatus. A device for this purpose was invented by a Frenchman, named Du Moucelle, of Paris, in 1853. The first practical temperature regulator in this country was invented in 1883 by W. S. Johnson, of Milwaukee, Wis., who placed it on the market in 1884. Some four years later W. P. Powers (then in the plumbing and steam fitting business), of La Crosse, Wis., devised a vapor thermostat for operating the draft doors of a furnace.

At about this time (1885) an electric thermostat was devised in Minneapolis, Minn., and later put on the market by the Electric Heat Regulator Company. This regulator in an improved form we shall later illustrate and describe.

These regulators and thermostats have been followed by numerous other varieties, all of which may be divided into two general classes, viz., electric and non-electric. In the list of the

electric thermostats and regulators are included the Minneapolis, Jewell, Beckam, Beers, Honeywell, and among the non-electric we find the Johnson, Powers, Regitherm, Howard, National, and others.

Many of the automatic regulators on the market are used principally for the control of steam and hot water heating apparatus, for the control of gas and liquids, and for the control of water and other liquids in tanks. This latter is styled "tank control."

We shall consider and describe only those which are especially used for the control of a furnace—those whose operation is directly governed by the temperature of the air within a room of a residence or similar building.

Electric Regulators

The Minneapolis, Honeywell, Jewell, Beckam and Beers regulators make use of devices for the electric control of the apparatus, which are quite similar in the operation performed. This appliance is placed on the wall of one of the principal living rooms of the residence. Fig. 90 shows the device as used with the Minneapolis regulator. Fig 91 shows the device with its shield or cover, on which is mounted a mercury thermometer. It consists of a frame holding a piece of metal in the form of a loop or ring with a tongue or strip of metal suspended from the bottom of the loop. One end of the loop is attached to the frame, the other end and the suspended tongue hanging free. The slightest change of temperature will expand or contract the ring causing a side movement of the suspended tongue or arm. An electric battery (consisting of two or three cells of dry battery) is used to generate the electric current through two wires, which are attached to posts or pins located one on either side of the suspended arm. Small thumb-screws or pins are set in these posts, so adjusted as to allow the points to almost touch the suspended blade. As the temperature of the room rises the loop expands throwing the blade against one set screw closing the electric circuit and operating the motor or driving power of the thermostat, which, in turn, operates the draft of the furnace by closing the draft door and opening the check door. When the temperature of the room has lowered the blade gradually works over against the pin on the opposite side of the frame. The action of the motor is then reversed and the draft door is opened and the check damper closed.

The driving power or motor of the Minneapolis, shown by Fig. 92 consists of a strong spring within the motor which is

wound up like the spring of a clock. Two arms or cranks pointing in opposite directions work the chains connected with the draft doors.

Fig. 90—Thermostat with Screen Removed.

Fig. 91—Thermostat with Screen Attached.

The motor of the Beckam, Fig. 93, and also that of the Honeywell regulator, is operated by a ball weight attached to a chain which is run over a sprocket pulley wheel and is wound or drawn up in much the same manner as the weights of an old-fashioned Swiss clock.

The Beers regulator uses two weights, each hung by a pulley wheel, as shown by Fig. 94, which figure also illustrates in a general way the method of adjusting the chains to the draft of the furnace.

Non-Electric Regulators

We will now consider some of the non-electrics, among which are found the Powers and Regitherm. There are other non-electric thermostats in the market, many of them being used only with a steam or a hot water heating apparatus. Those mentioned here will be sufficient, however, to show some of the methods employed.

The Powers thermostat operates on the vapor principal. On the wall of one of the living rooms of a residence is located a metal disc composed of two plates fastened together at the edge. This is about 12 inches in diameter, and about 1 inch thick.

Fig. 92—Motor.

Fig. 93—Beckam Regulator.

The metal of the plate is spun in corrugations to give flexibility. A liquid is placed within the disc which will vaporize at a very low temperature, and which generates a pressure within the disc. Fastened to the back of the disc, and opening into it, is a small hollow tube. Through this tube the pressure of the vapor is conveyed to a diaphragm motor located above the furnace. The pressure on the disc of the diaphragm lowers the arm, to the end of which the draught doors are connected by chains. This movement closes the draught door and opens the check damper of the furnace, checking the fire. As soon as the room cools, the pressure on the diaphragm is removed. The arm of the motor then returns to its former position, closing the check and opening the draught door of the furnace.

Fig. 95 shows the diaphragm motor of the Powers regulator and the method of attaching same to the furnace. It is held in position above the furnace by a pipe rod, attached to ceiling. The small hollow pipe, conveying the power from the thermostat to the motor, can be seen as it passes through the space between floor and ceiliing, and thence along the ceiling to point above the motor, where it drops, and is connected into the upper side of the diaphragm.

The Regitherm is a temperature regulating device, entirely different in principle from any of the others. The thermostat and motor are combined into a single instrument which may be called

a thermal motor. Fig. 96 will give a general idea of its appearance. The vital part or motor consists of a closed metal bellows, so constructed that it readily expands and contracts along the line of its axis. A cross section of the folds is roughly shown by Fig. 97. The theory of this construction is that strain is brought on the point marked A, and no bending occurs at B, which is the point of greatest weakness.

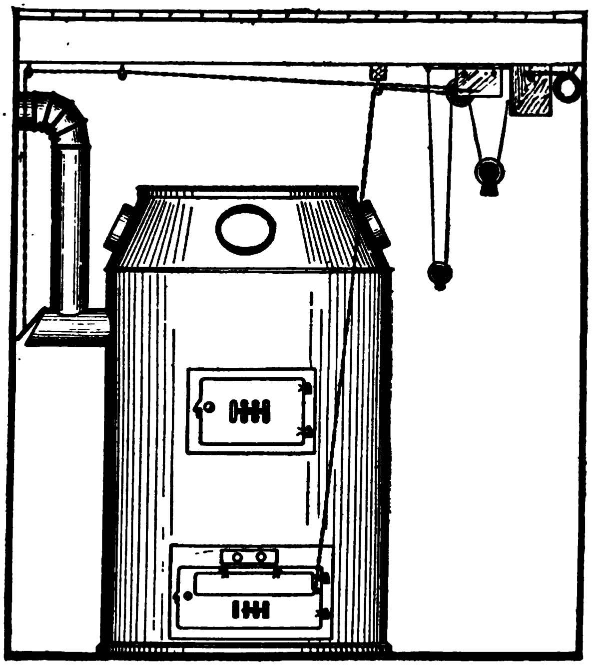


Fig. 94—Beers Regulator Attached.

This bellows contains a quantity of volatile liquid, extremely sensitive to minute variations of temperature. The bellows is rigidly attached at one end to the frame work, and at the other to a lever, which is moved up and down by the expansion and contraction of the bellows.

A unique feature of the device is the fact that the power to adjust the dampers is derived entirely from the changes in temperature of the air of the room in which the Regitherm is located, and the movement of the bellows is communicated to the

dampers of the furnace by means of a small steel wire or cable passing over pulleys and connected to a lever above the furnace.

Unlike most of the temperature regulators, the Regitherm does not accomplish the desired result by the alternate opening and closing of the dampers. Some intermediate position is assumed, and a slight shifting of the dampers takes place whenever the temperature conditions in the rooms above are changed. It may be set to control the temperature at any point between 60 and 80 degrees.

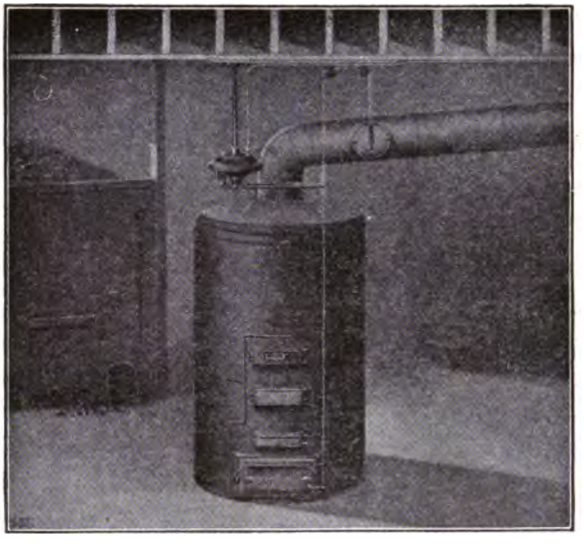


Fig. 95—Diaphragm Motor Attached to Furnace.

We have given somewhat of the history of temperature regulation, and quite fully described some of the various apparatus, in order that the furnace man may post himself regarding the subject and also gain a general knowledge of the apparatus used, and the methods adopted to automatically control the work of the furnace.

It is a part of the furnace business which has been neglected, and for no apparent reason. The average type of regulator is easily installed, reasonable in price, and its sale can be made a profitable and desirable adjunct to the furnace business.

The value of a good temperature regulator seems to be neither understood nor appreciated by the heating contractor.

What the governor is to an engine the thermostat is to a furnace. The governor, attached to an engine, prevents the engine

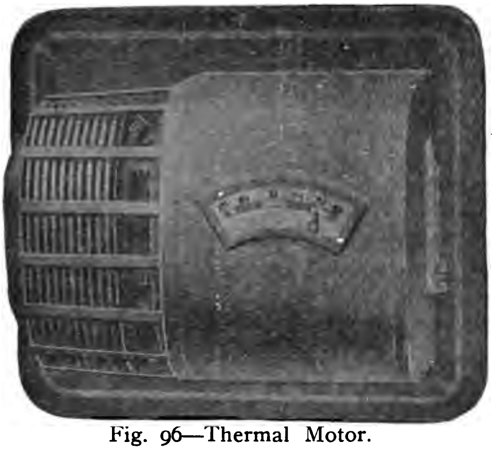


Fig. 96—Thermal Motor.

from "running away" or speeding when the load or work it is doing is suddenly lightened,—in other words, it regulates the speed of the engine automatically, preventing useless waste and possible danger.

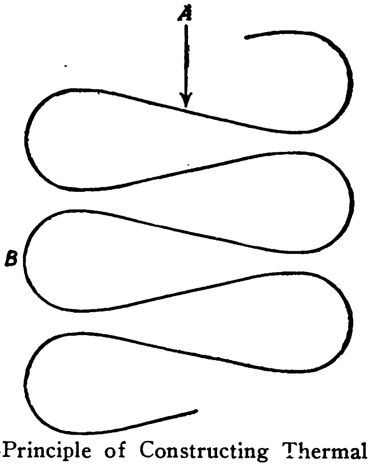


Fig. 97—Principle of Constructing Thermal Motor.

The thermostat or temperature regulator, attached to a furnace, prevents the overheating of the building and consequent waste of fuel. It also prevents possible damage due to overheating the furnace.

By selling and attaching temperature or automatic damper regulators the furnace man not only provides the means of safety and economy to the owner, but in so doing adds another branch to his business which will materially increase the profits of the same each season.

How to Sell Thermostats

We have mentioned three arguments in favor of temperature regulation,—economy, healthfulness and comfort. These features of economy and satisfaction are prominent factors to be considered.

Thermostats are easily sold when their merits are brought to the attention of house owners in the right manner. Practically no argument is necessary on the part of the heating contractor to effect the ready sale of a thermostat when the convenient and economical features above referred to are made known to him.

Considering the first feature, that of economy, we may say that one shovelful of coal saved daily for the heating season will approximate one ton saved for the season. Intermittent firing or coaling of the heating apparatus is one of the wasteful items to contend with. Remembering how frequently it has been necessary to coal the furnace, due to forgetfulness in leaving the draft doors open, the owner will readily understand the situation when the statement is made that the use of any good system of temperature regulation will save from one-quarter to one-third of the fuel ordinarily consumed when operating the furnace without such a device.

How can we show the owner that this saving is possible? There should be no trouble in proving to the owner that intermittent firing is costly. We have already referred to the temperature bulletin issued by the U. S. Government, which shows a wide variance of the demands for heat; it being necessary in certain portions of the extreme north to raise the temperature frequently through 80 to 100 degrees, while in southern cities, for instance in Charleston, S. C., it is necessary to raise the temperature an average of 47 degrees. When we consider that a change of 10, 20 or 30 degrees, up or down in the temperature, frequently takes place within a few hours time and that the regulator will condition the fire in the furnace to accommodate this sudden change, we can understand that automatic regulation will effect a great saving.

In this country a week of solid cold weather is the exception rather than the rule. In Canada the week of mild weather in winter is the exception rather than the rule. Consequently, we have very much more need of temperature regulation in the United States than they have in Canada.

Of the second feature, healthfulness, we need add but little in addition to what has already been said, as all who have investigated the subject know the desirability of keeping the temperature uniform within the home. Uniformity of temperature is considered as necessary as is ventilation or heating.

The next feature to consider is personal comfort, and here is the chance for the delivery of a telling and conclusive argument. In business, as well as in pleasure, this age is specialized with automatic devices. Think of the number of automatic devices which increase the efficiency of business, and the intensity of pleasure. Then why not automatic personal comfort? Doesn't that sound good? The heating season comes just as regularly each year as does dinner time each day. The comfort and convenience of having an automatic watchman in charge of the furnace to open and close the drafts as required, is an argument which ought to appeal as well to the busy man as to the seeker after personal comfort.

The Cost of Heat Regulation

Automatic temperature regulating devices cost the owner from twenty-five to fifty dollars, according to the character and make of the device. At the price named there is a fair profit to the furnace contractor for installing the same.

As a matter of fact, the thermostat really costs the house owner nothing, for it saves many times the interest on the investment each season until the saving made pays the cost of the installation, after which it earns money for the owner at a greater rate than any ordinary business investment he may have. It would seem then that the cost—whether twenty-five or fifty dollars—is not prohibitive. In fact, it should not be considered when the economical, healthful and comfortable features brought about by its use are known and appreciated.

How to Attach Thermostats

It is possible that the failure to sell and install more thermostats is due to fear, on the part of the heating contractor, that he may not be able to install the apparatus correctly.

If it is a fact that the furnaceman is letting slip this opportunity to better his work and add to his profits through ignorance of the construction and method of installation of automatic heat regulators, a very little investigation of the subject will show that the average thermostat is quickly and easily attached and adjusted.

All thermostats have a positive and a negative action of the motor or other mechanism which controls the drafts. This positive or negative action of the motor or other mechanism opens or closes the draft and check doors automatically in conjunction with each other, the check damper opening as the draft door closes, and vice-versa; therefore no matter what type of a thermostat is to be installed it must be attached in such a manner that the draft and check doors will operate together, and to accomplish this result the chain connections to the doors are run over pulleys hung from the joists above the furnace and connected in the most simple manner.

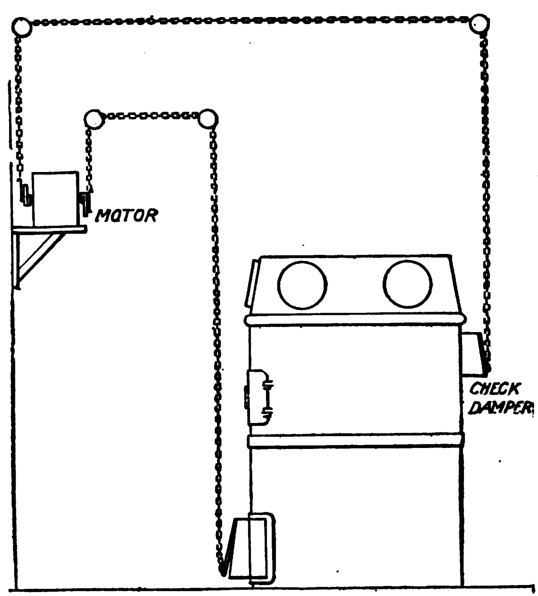


Fig. 98—Method of Attaching a Minneapolis Regulator.

Fig. 98 illustrates a method of connecting the Minneapolis Regulator. The driving power of this thermostat is a motor operated by a strong spring and its approximate location is shown on the sketch. Note that in order to prevent the sagging of chains between pulleys a wire is employed, to which the ends of chains running over or through the pulleys are attached.

Fig. 99 illustrates the manner of attaching a Honeywell Regulator to a hot air furnace. The driving power of this regulator

is a motor operated by a weight. This weight is suspended by a chain, the links of which fit over the teeth of a sprocket, and the winding up of the motor consists of pulling up the weight much as one would wind an old fashioned grandfather's clock.

Practically all of the so-called electric thermostats make use of two cells of dry battery for supplying the current for controlling the motor, and through this the drafts of the furnace.

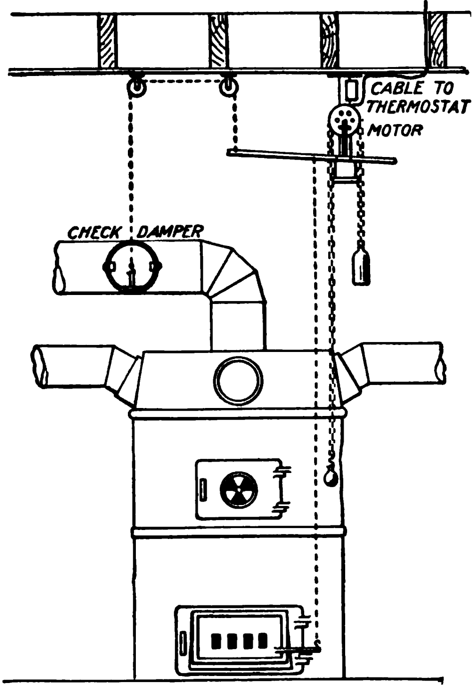


Fig. 99—Method of Attaching a Honeywell Regulator.

Three copper wires of a size simiar to that used for connecting door bell batteries are insulated in red, white and blue covering and encased in the form of a single cable. These wires are attached to various parts of the thermostat where directed, and the cable then extends down to the basement, and to the motor of the regulator, where the wires are separately connected to certain parts of the motor.

The cells of dry battery should be connected together as shown by Fig. 100 which represents the top of the cells. The white covered wire in the cable should be attached to the batteries as indicated on the sketch. The wiring of all thermostats and regulators is practically the same, and the regulator is now ready for adjustment and attachment to the furnace.

In this connection we desire to speak of the check damper of the furnace. The check damper door of many furnaces is inaccessible for use with a regulator and also is frequently not of proper construction. When this is found to be the case it is best

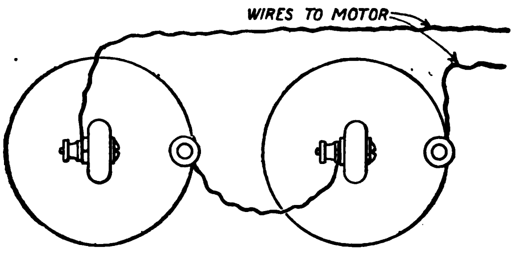


Fig. 100—Method of Connecting Dry Battery.

to employ a specially designed balanced check damper, as illustrated by Fig. 101. This check damper should not take the place of the regular smoke pipe damper, which should continue to be used and which should be located at a point in the smoke pipe between the furnace and the check damper.

It would be quite impossible in a brief article to describe the manner of installing all thermostats now on the market. We can

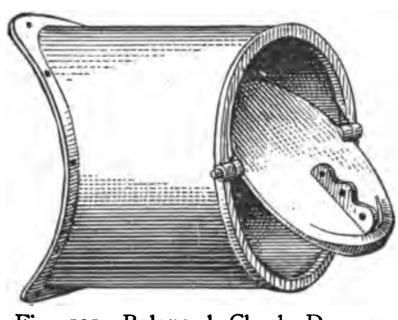


Fig. 101—Balanced Check Damper.

say, however, that all are substantially alike in principle and are easily attached when this principle is clearly understood.

Automatic Draft Regulators

Before leaving the subject of temperature regulators we desire to call attention to another type of device for handling the drafts of the furnace. We refer to a device for putting the drafts on the heater at some pre-determined hour of the morning.

Fig. 102 illustrates one type of such apparatus and Fig. 103 another type. These devices are known as draft regulators, although, strictly speaking, they do not "regulate" the draft.

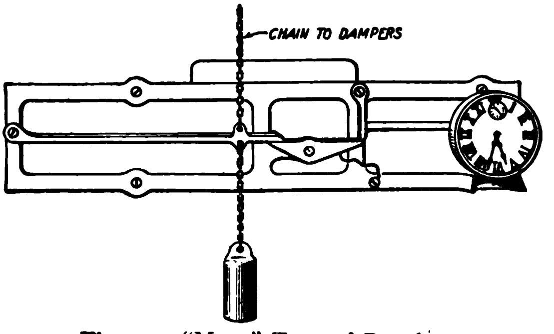


Fig. 102—"Mono" Type of Regulator.

The office of this type of regulator is to automatically close the check damper and open the draft door of a heater in the morn-

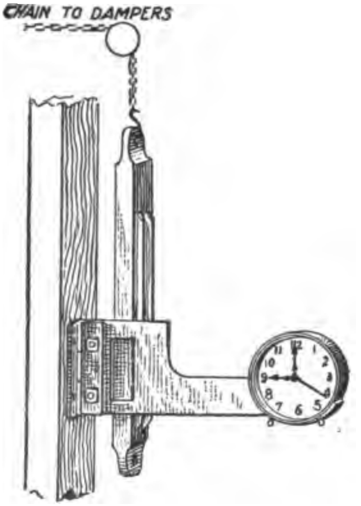


Fig. 103—"Peerless" Type of Regulator.

ing, thus allowing the fire to burn and the rooms to become warm that the family may rise and dress comfortably.

Operation and Installation

An ordinary type of alarm clock is the medium by which this type of regulator is controlled.

Assuming that it requires about an hour to heat the house comfortably and that the hour of arising is seven o'clock, the heater is coaled in the evening before retiring and the dampers

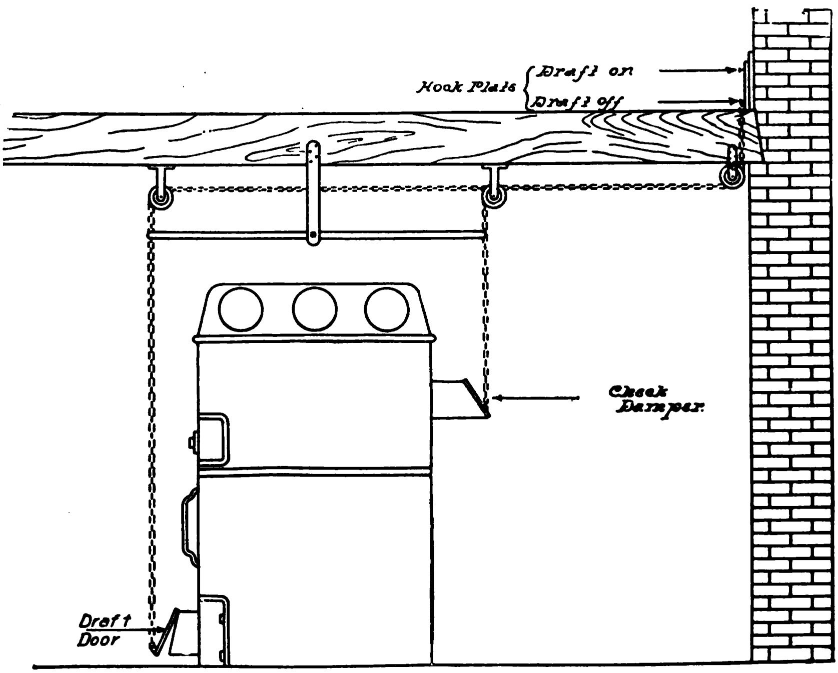


Fig. 104—Controlling Drafts from Living Room.

are then closed. The alarm clock is then wound and set at six o'clock. There is no alarm on the clock, but in its stead the mechanism of the clock trips a little lever which allows a weight to fall a distance of twelve to fifteen inches. Chains are attached to this weight, which connect with the drafts of the heater, and when the weight falls these chains open the draft door and close the check damper.

This has been called an invention for a lazy man. We think, however, that the method of running the apparatus with drafts closed at night and opened automatically in the morning will appeal to any person who realizes the healthfulness of sleeping in a cool room and how comfortable it is to rise and dress in a warm room. Aside from these features, the use of such a device will cause a considerable saving in fuel.

Chain Control of Drafts

A simple method of controlling the drafts of the furnace from one of the living rooms on the first floor should also be provided as an accessory to the furnace.

A rod of light weight iron may be hung from an arm located above the furnace and the draft doors of the heater connected to this rod by means of chains. From one end of the rod, a chain, passing over pulleys, is connected to a plate located against the base-board, in a room above the furnace, by a hook on the end of the chain, and an eyebolt on the plate. Hooking the chain to the upper eye opens the draft doors of the furnace and lowering it to the bottom eye closes the drafts. Fig. 104 shows the method of making this attachment. The ornamental plate may be of cast iron, bearing the name of the heating contractor and is a standing advertisement for him.

Some furnace manufacturers furnish similar plates and chains, but we find that these are seldom made use of by the furnace men.

It is the consideration given by the live furnace contractor to devices of the above description that makes for success, and marks his work as above the average in the consideration of the house owner and possible customer.

CHAPTER XVI

FUEL: ITS CHEMICAL COMPONENTS AND COMBUSTION

To the great mass of people coal is known simply as coal—anthracite or bituminous—hard or soft. Most users of coal as a fuel for heating or cooking accept of conditions as they are found locally, and burn the fuel found—or more properly sold—in the local market, without regard to its value as a heat producing commodity. To such people a ton of coal is simply a ton of coal—nothing more.

We wish to discuss this question, and try to determine and make clear what preparation is necessary to properly burn certain kinds of fuel in the hot air furnace.

The principal factor of value in coal for use as a fuel for heating is the amount of fixed carbon it contains—carbon being the principal heat producing matter in all fuels.

It is said by those wizards of the present age, the chemists, that all coals contain two exactly opposite matters, namely: combustible or heat producing matter, and non-combustible or non-heat producing matter. They sub-divide these matters as follows:

Combustible Matter—
- Volatile Matter (Gas)
- Fixed Carbon (Coke)

Non-combustible Matter:
- Moisture (Water)
- Ash (Refuse)

In addition to the above, there is present a rank impurity called sulphur. This is sub-divided as follows:

(a) Volatile sulphur, which disappears in the smoke and products of perfect combustion; and

(b) Iron pyrites or sulphuret of iron, which causes the coal to clinker and run on the grate bars.

To deviate a little from the subject, we desire to say that many of our readers live in localities where a fuel is burned which is mined locally, and where these last conditions are particularly

noticeable. For instance, in certain sections of Illinois a coal is mined and used which is fed to the furnace or stove in large chunks. A short time after the coal has been supplied to the furnace or stove, and while the large chunks are still intact, a slight rap with a poker or slice-bar will cause it to separate or break into small pieces, and after burning for a period it becomes semi-liquid and can be stirred on the grate like a mass of molten lava.

A like condition is found in certain varieties of coal mined in West Virginia, Ohio, and some other localities.

Another condition, due to the presence of iron pyrites in some varieties of coal, is the fusing or attaching of particles of ash and partially burned coal into a mass of clinker. This is particularly noticeable in furnaces or heaters not properly constructed to admit of perfect combustion of the fuel.

Returning to the consideration of the chemical analysis of coal, as given above, we may say that all coal contains gas, coke, water, sulphur, and refuse, and for all purposes the coal which contains the most fixed carbon (coke), together with the greatest percentage of volatile matter (gas), is the most valuable for use as a fuel.

We say "for all purposes," as the great mass of users of coal as a fuel fail to consider that certain varieties of coal are best adapted for certain kinds of work.

The proportions of volatile matter and fixed carbon, as found in some varieties of coal, seem to have been blended for certain uses.

Some anthracite coal is very rich in carbon, containing possibly 85 to 90 per cent., and low in the percentage of volatile matter (gas); does not clinker, and when once thoroughly ignited will burn for a long period. These features make it particularly adaptable for use in stoves, furnaces, and other heating apparatus.

Some cannel coal is so full of gas and so low in carbon, containing as high as 60 per cent. of volatile matter, that it can be lighted with a match. While speaking of cannel coal, we may mention the fact that the word "cannel" is a corruption of the word "candle." In Lancashire, England, the name "candle" was first given to this variety of coal owing to the fact of its being easily lighted, and that when kindled it burns with a highly luminous yellow flame, much like a lamp, without melting. The Lancashire pronunciation of the word candle is "cannel," and in England and Soctland the farmers used this coal for candles —hence its name.

Experience has taught us that it is unprofitable to burn anthracite coal under boilers used for power, and that where the generation of steam is the main object sought, we should use a coal with a good percentage of fixed carbon and a fairly large percentage of volatile matter, or gas, as such coal contains a larger amount of heat units than any other combination or blending of these elements. On the contrary, it has been proven conclusively that anthracite is far superior to any bituminous coal for use in a stove or heating apparatus, owing to the larger percentage of fixed carbon and the smaller percentage of volatile matter contained in it.

This may seem strange to those who have not studied the subject, and yet it is easily accounted for. When under a factory or other power boiler, the best and most economical results are obtained from burning the largest possible number of pounds of coal per hour on each square foot of grate, and a blower is frequently used to supply large quantities of air, and thus stimulate combustion in order to accomplish this result. when the latter conditions prevail, we demand a slow rate of combustion and try to burn as little coal per square foot of grate per hour as possible to maintain the desired temperature.

Tests have shown that certain manufacturing needs demand a certain grade of coal—that for each different kind of coal there is a specific manufacturing or commercial need.

We have compared authracite and cannel coal as being the extremes in the percentage of fixed carbon and volatile matter contained. There are several kinds of coal which may be classified between these two varieties. These may be classified as follows, the percentages given being a fair average:

Kinds.	Volatile Matter.	Fixed Carbon.
Anthracite	7 per cent.	85 to 90 per cent.
Semi-Bituminous	18 per cent.	75 to 80 per cent.
Bituminous	24 per cent.	70 to 72 per cent.
Semi-Gas	30 per cent.	60 to 65 per cent.
Cooking	33 per cent.	58 to 60 per cent.
Gas	37 per cent.	55 to 58 per cent.

Our discussion of fuels would not be completed without saying a few words about coke.

Coke is a brittle, porous solid. It is a dark gray in color, and is artificially manufactured by a process called "coking," which consists in expelling all of the volatile matter (gas) from bituminous coal, this process being usually carried on in ovens made of firebrick. Charcoal is introduced into the top of the oven and, being lighted, a little air is admitted through openings

in the front. When the coal in the oven ceases to emit smoking vapors the supply of air is cut off, and the oven allowed to cool for a day or two. A door in the front of the oven is opened, and the hot coke is then raked out. Water is thrown upon it to stop further combustion. A net ton of coal (2,000 pounds) will make from 1,000 to 1,600 pounds of coke, depending upon the character of the coal. Coke does not smoke when burning, and gives off a large amount of heat.

As we are considering the relative value of different varieties of coal as a fuel for heating apparatus, rather than the value of the coal as a commodity, this latter subject has no place in our discussion, and yet there is one thought to which we wish to call attention.

As stated, from 1,000 to 1,600 pounds of coke are available for each 2,000 pounds of bituminous coal thus converted.

By inquiry at any gas-making establishment—gas-works we call it—where coal-gas is produced, our readers will find that about 10,000 cubic feet of gas are obtained from 2,000 pounds of bituminous or coal-gas. When we consider the value in heat units, or as a heat producer, of 1,000 to 1,600 pounds of coke plus 10,000 cubic feet of coal-gas, we may learn something of the real value of one tone of bituminous coal.

To burn coal, coke, gas, or any other fuel it is necessary to mix oxygen with it. Therefore it is necessary to admit a sufficient amount of atmosphere to supply this oxygen. The carburetted hydrogen (gas) and the carbon of the fuel must each be supplied with the necessary amount of oxygen, and be kept at the required temperature to produce the chemical action necessary for perfect combustion.

Some idea of the volume of air necessary may be obtained by considering the statement that for the complete combustion of the volatile constituents of a ton of coal 100,000 cubic feet of air is required. This is figured from certain definite data, which show that we are obliged to make use of five cubic feet of air to supply one cubic foot of oxygen, and to obtain 20,000 cubic feet of oxygen, the amount necessary for the complete combustion of a ton of coal, requires five times twenty or 100,000 cubic feet of atmosphere air.

The admission of too little air will allow much of the gas to pass off unburned, and the admission of too much air will cool the fire or combustion chamber of the furnace and reduce the temperature, thus preventing perfect combustion.

From the above statement, it is evident that in order to obtain the best resuts form the fuel used, we must build our furnace in such form that the gases or volatile matter in the fuel can be

properly ignited and burned, and from this, also, we may establish the fact that a furnace which will give good results with Pennsylvania anthracite as a fuel will prove a flat failure with Illinois bituminous coal.

It is entirely a matter of proper furnace construction, taking into consideration the character of the fuel to be used and the locality where the furnace is to be installed, and in our consideration of the construction of furnaces as best adapted for burning certain grades of fuel, we shall neither discuss the production of the apparatus from the standpoint of the manufacturer, nor cover the merits of any particular type of furnace.

The several simple sketches, Figs. 105, 106 and 107 illustrate the three general methods employed in furnace construction to provide a means for the passing off of the smoke and products of combustion, and there are many forms and variations of each idea.

Fig. 105 represents the direct method and involves a direct passage into the smoke flue of the products of combustion. By it all air moving through the furnace is warmed by the direct radiation of the heat from the fuel consumed. All furnaces of this type are wasteful of fuel, and yet there are certain grades of coal, full of iron pyrites, sulphur and other impurities, which can be successfully burned only in a furnace of this kind. In any other type the tarry smoke will encrust the heating surfaces of the furnace, rendering them practically useless, or what is still worse, will completely clog the flue passages through it.

Fig. 106 illustrates the semi-indirect plan of furnace construction, and it is safe to say that ninety per cent. of the manufacturers adopt this method or some form of it in their type of warm air apparatus. It is well known that in order to successfully burn a large percentage of the coal gas or carburetted hydrogen, it must be retained within the fire chamber until sufficient oxygen can mix with it to produce combustion. This means that for every cubic foot of coal gas extracted from the fuel, two cubic feet of oxygen must be applied or enter into union with it to cause perfect combustion, and, as stated in the precious chapter, it will be remembered that in five cubic feet of reasonably pure air there is present but one cubic foot of oxygen.

Hence, to properly consume a cubic foot of coal gas requires the admission of ten cubic feet of air into the fire chamber of the furnace.

Now, in order to do the work advantageously this supply must be admitted at a certain time, a certain place, and in a certain manner, and it is by reason of these essential requirements that the goods of so many manufacturers of furnaces

have "fallen down" on efficiency tests. As stated before, too little air will not prevent the gas from passing off unburned, while an overabundant supply will cool the fire chamber too much and retard combustion.

In the effort to retain the gas within the furnace until it shall be consumed, the manufacturers use some form of the indirect method illustrated by Fig. 106, although this effort is exerted in vain unless other matters are also provided for at the same

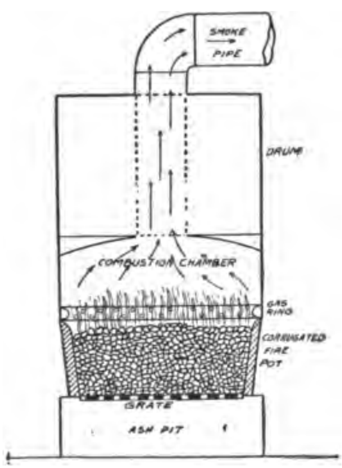


Fig. 105—Construction for Indirect Draft.

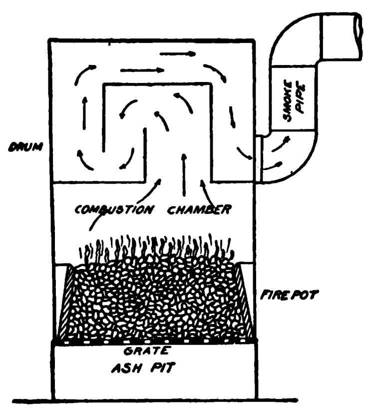


Fig. 106—Construction for Direct Draft.

time. An active fire will produce a cubic foot of coal gas very quickly. Suppose the rate of combustion is four pounds per square foot of grate per hour, and the size of grate three square feet. The hourly consumption of coal in such a furnace would be twelve pounds. If we consider bituminous gas coal as a fuel (10,000 cu. ft. gas to a ton of 2,000 lbs.), the coal burned will produce about sixty cubic feet of gas per hour, each pound of fuel burned giving off five cubic feet of gas, and requiring fifty cubic feet of air to consume it.

Now, we have said that the air must be admitted at a certain place, time and manner. The place should be at a point just above the normal level of the fire in order that the air may mingle with the gases arising from the fuel. The gas ring appliance usually included, and shown on Figs. 105 and 107, is made of cast iron. A fire-pot may be provided with firebrick lining so set, or held in place, as to provide an air space between

the brick and the outer iron cylinder, the air passing upward from the base and into the fire chamber through small holes in the lining, as illustrated by Fig. 108.

The proper time for the admission of this air is when the gas is burning off from a fresh charge of cool, because probably eighty-five per cent. of all gas in the coal burned is given off during the hour following the time that the additional fuel is added, provided the draught is on the furnace.

The manner in which this air should be admitted is in small sprays above the fire, and its temperature should be practically the same as that of the gas. When the supply is taken in through a gas ring, or through the top of the firebrick, as shown by Fig. 108, its velocity is about four times as great as that of the air passing in the lower draught door and upward, and should this volume of air move upward through the coal, the rate of combustion would be so rapid that a large share of the gas would pass out of the smoke pipe unconsumed.

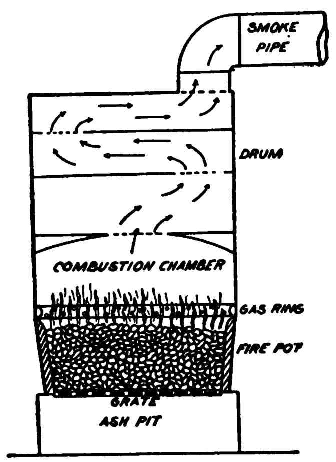


Fig. 107—Construction for Semi-Indirect Draft.

The principle shown by Fig. 107 is used in the construction of furnaces for both hard and soft coal.

The indirect method illustrated by Fig. 106 is adapted more particularly to building furnaces for hard or anthracite coal, and a wonderful variety of forms and ideas is followed by manufacturers in carrying out the principle shown. The percentage of volatile matter in anthracite coal is so small that little or no attention is given to burning the gases. Combustion is not so rapid as with soft coal, and any air admitted above the fire has a tendency to chill it. The temperature in the fire

chamber should be high, in order to provide for complete combustion, and the firepot for burning anthracite should be almost straight up and down or possibly a little larger in diameter at the grate line than at the top; also, its surface should be corrugated.

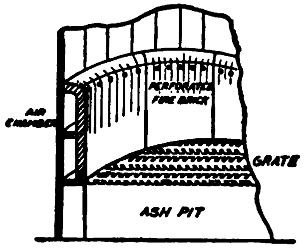


Fig. 108—Fire Pan with Air Holes in Lining.

By considering the foregoing facts regarding the furnace construction we shall accept the following definite conclusions:

(a) That furnaces should be selected according to the character of the fuel to be used.

(b) That the gas or volatile matter in all coal other than anthracite is of greater value than the carbon (coke) for heating purposes.

(c) That, in order to utilize the greatest number of heat units in bituminous and semi-bituminous coal, it is necessary to make proper provision for burning the gas first and the coke last, or, stated in another form, to appropriate the full value of the gas for heating, retaining the coke for rekindling requirements.

(d) That the loading of a fire with fresh fuel obstructs the volume and velocity of the air admitted through the grate, making it necessary to inject a sufficient quantity of air above the fire to properly burn the gases.

(e) That unless this deficiency is provided for all combustible gases, such as hydrogen, carburetted hydrogen, and carbonic oxide, will escape up the chimney flue, the smoke plainly indicating the loss sustained.

(f) That in introducing heated, and consequently rarefied air, into the combustion chamber of the furnace in small jets, through a gas ring, or perforated firebrick, a sufficient supply of oxygen can be admitted without cooling the gases and perfect combustion obtained from the thorough mixture of the oxygen with the gases.

As an all-important part of a furnace, the grate should be of such shape and character that the ashes may be removed from the firepot without stirring up the body of unconsumed coal

lying above them. The nature or size of the opening between the bars has little to do with a greater or lesser consumption of coal. The grate is simply a cradle which holds the fuel and the amount burned is governed by the quantity of air passed through the grate.

It is possible to consume the fuel without benefit, under which circumstances, of course, the combustion will not be perfect, and while the fire appears dead or passive, yet more fuel is burned than would be the case if the combustion were positive and the fire active. The remedy for such a condition is found in the admission of air—oxygen—in the right place and manner and in sufficient quantity.

Coal: The Universal Fuel

A brief narration of the facts regarding the discovery and development of the coal deposits of the world, and particularly those of the United States, will prove interesting to all persons connected with the manufacture and installation of heating apparatus.

Coal is the universal fuel, and without its use it is doubtful if the nations of the world could have made such progress in manufacture and civilization as history has recorded.

We are accustomed to think of coal as being principally a product of the United States; and while it is true that we now lead all other nations in the tonnage of coal mined, this standing has been reached only in recent years.

We know that more than 2,000 years ago coal was an article of commerce in certain parts of the Chinese empire and had been known for years prior to that period. It is also recorded that coal was shipped into London in the year 1240.

Virginia bituminous coal was mined as early as the year 1750 and in 1768 anthracite coal was mined in the Wyoming Valley, Pennsylvania, near what is now the city of Wilkes-Barre, and in the years 1770-76-91 coal was mined in other sections of Pennsylvania.

It is related that in the year 1812 Colonel Geo. Shoemaker of Pottsville, loaded nine wagons of coal from the Schuylkill region and hauled it to Philadelphia where, with difficulty, he sold two loads and gave the other seven loads away. He was regarded as an imposter and with some trouble avoided arrest by getting out of the city.

White & Hazard, owners of a wire-works at the Falls of Schuylkill, bought one of the loads and a whole night was spent by their workmen in efforts to make the coal burn. They gave

up and quit their work, leaving the door of the furnace closed and one of the workmen returning for some forgotten clothing found everything red-hot.

This effort to burn coal is exceedingly interesting when we consider that 100 years later (1912) the United States produced about one-third of all the world's supply, leading England by millions of tons and Germany, her next nearest rival, by a tonnage three times greater.

As a matter of fact this great development has taken place within the last forty years as the coal production in the United States in 1866 was less than 15,000,000 tons.

CHAPTER XVII

CEMENT CONSTRUCTION FOR FURNACE MEN

When engaged in the business of installing warm air heating appartus the sheet metal worker should be independent of other contractors. In making this statement we mean to say that in order to reap the full benefits accruing from a contract the furnace man should install his work without the services of a carpenter or mason. He should be sufficiently familiar with the use of carpenters' tools to do his own cutting and framing, and he should also be able to construct foundations, cold air pits, and ducts, and to instruct his men how to build them without the assistance of a mason or cement contractor.

The present period is sometimes called the age of cement, by reason of the fact that cement is now so generally used in building construction of all kinds, and we desire to call attention to the proper method of mixing and using cement.

A volume would be required to treat this subject in a thorough manner. We shall, however, in this brief article be able to show how to use cement successfully, and also to point out the reason why so many furnace men fail to obtain proper results when attempting to build pits and ducts of concrete.

Concrete Mixtures

All cement mixtures are not alike in strength or consistency. A certain mixture that might be best for one class of work would not do for work of another class. Mixtures of concrete of greatly different strength and costs can be made of the same materials, simply by combining them in different quantities.

In our discussion of concrete mixtures we shall make use of two terms which should be explained. These terms are *aggregates* and *voids*. *Aggregates* are the solid and coarse ingredients which are bound together by the cement in making a mass of concrete. Materials such as sand, gravel, trap rock or crushed stone, cinders, etc., are known to cement workers as aggregates.

Voids are the air spaces between the particles of aggregates which must be filled or removed from all cement work in order

to make the work substantial. For example, the voids in sand are filled with cement and this mixture is used to fill the voids in gravel or broken rock.

The ability to judge by sight or determine by test the proportions of materials for a cement mixture is gained only through long experience, and it is essential that the mixture be right for the work in hand. A certain mixture for a foundation pit or duct in a cellar which is always dry would not do for building a foundation pit or duct, which of necessity must be watertight on account of a cellar being wet at certain periods of the year, nor would a mixture suitable for building a sidewalk be right for use in constructing a cistern.

Concrete mixtures are classified in two different ways. First as to richness, meaning the quantity of cement used, and secondly as to consistency or wetness.

When so classified a cement mixture is known as rich, medium, ordinary and lean. A 1 :2 :4 mixture would be called a rich mixture. The formula 1 :2 :4 indicates one barrel of cement (four bags to the barrel) to two barrels of sand, and four barrels of gravel or broken stone or other coarse aggregates.

A 1 :2.5 :5 mixture is one barrel of cement, two and one-half barrels of sand and five barrels of broken stone or loose gravel, and this combination of materials would be classified as a "medium" mixture.

A 1 :3 :6 mixture measured in like manner is known as an "ordinary" mixture, and a 1 :4 :8 combination of cement, sand and gravel as a "lean" mixture.

In consistency the mixture may be "very wet," "medium wet" or "dry," the amount of moisture necessary depending upon the work for which it is intended.

For use in building foundations and ducts for furnace work a "medium" or "ordinary" mixture "medium wet" is desirable, provided the pit or duct is not to be waterproof. If the pit or duct must be waterproof on account of a wet basement, or trouble at certain periods from surface water, the mixture should be a 1 :2 :4 (rich) or a 1 :2.5 :5 (medium), and in consistency, medium to very wet.

Mixing Concrete

There are several methods of mixing the concrete. The sand and cement may be mixed dry, and this mixture spread layer upon layer upon the broken stone, gravel or aggregate before the water is added, or the sand and cement may first be mixed with water into a mortar, and this mortar then mixed with the

broken stone or gravel, after which, in either case, it should be turned with a shovel until a thorough mixture of the ingredients is obtained, or until all particles of the aggregates are thoroughly coated with the cement paste.

There are several kinds of cement to be had, the best for general use being that called Portland.

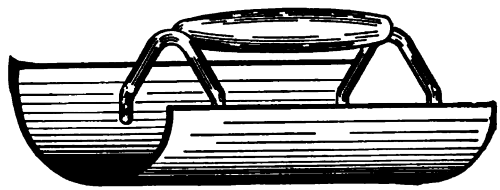


Fig. 109—Trowel for Round Corner Work.

Portland cement consists principally of limestone and slag crushed separately and dried to remove all moisture, after which each ingredient is ground extremely fine. After being combined in a certain proportion this mixture is calcined or burned to a clinker. This clinker is then cooled, pulverized fine, and mixed with a certain quantity of gypsum, when it is ready for the storehouse, where it is kept free from moisture until shipped or supplied for use.

The Tools

For use in constructing cement ducts, pits and other work of like character, but very few tools are required and these are inexpensive.

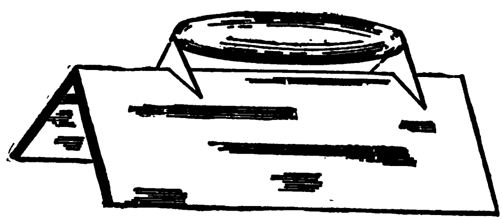


Fig. 110—Trowel for Square Corner Work.

Other than a shovel, hoe and ordinary trowel there are a few tools which are useful and convenient. Fig. 109 illustrates a smoothing trowel for round corner work. Fig. 110 a smoothing trowel for square corners. Fig. 111 another form of a round corner smoothing trowel. Fig. 112 shows two forms of a tamper (a tool for tamping or pounding the cement mixture to remove the voids), which may be made from any heavy iron casting planed smooth on the lower side and to which a handle may

be used. These tools and a leveling board and straight edge are all that the furnace man will require for the class of cement work he will be called upon to construct.

Determining Quantities

In connection with cement work the following data will prove useful in determining quantities.

Fig. 111—Trowel for Another Form of Round Corner.

A bag of natural cement weighs 94 pounds.
A bag of Portland cement weighs 94 pounds.
A barrel of natural cement equals three bags, and weighs about 282 pounds.
A barrel of Portland cement equals four bags, and weighs 380 pounds.
A cubic foot of crushed or broken stone weighs about 90 pounds.

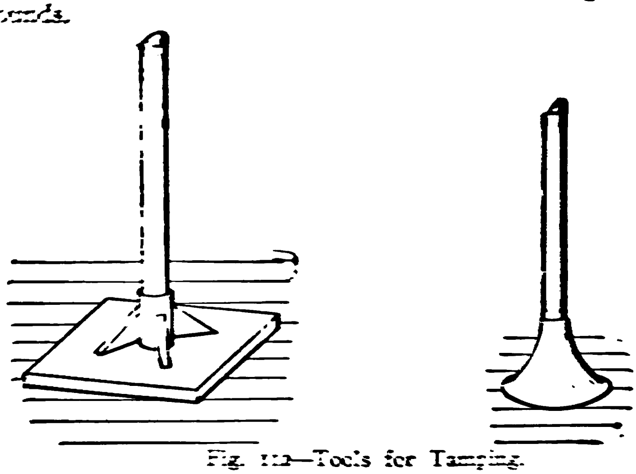


Fig. 112—Tools for Tamping.

One bushel of cement and two bushels of sand mixed together to form a cement mortar will cover 3⅜ square yards one inch thick, or 6¾ yards one-half inch thick. (This rule applies for a smoothing mixture for use over rough concrete, brick or stone.)

Methods

To make cement mortar (as above) adhere to old or finished cement work, the surface of the old work should be thoroughly soaked with water, then dust on a little neat cement, after which apply the mortar coat before the dusted cement has set.

Another method equally as good is to mix a thick paint of cement and water and brush it carefully over the surface of the old work after it has been thoroughly wet with water; then apply the mortar coat quickly before the paint coat has set.

It is not a difficult matter to construct good cement work if care is exercised in the selection and mixture of matcrials. Do not guess at quantities. All materials used should be carefully measured or weighed.

CHAPTER XVIII.

CONSTRUCTION AND PATTERNS OF FURNACE FITTINGS

Including Bonnets, Collars, Elbows, Cold Air Connections, Register Boxes, Transition Boots, Shoes, Tees, Offsets, Etc.

By WILLIAM NEUBECKER

This chapter treats the various methods for developing and constructing the many styles of furnace fittings, as well as the rule to be followed for finding the true angles of elbows from given dimensions. In designing the shape of any fitting care must be taken not to reduce the given area, but to have the same area throughout the entire fitting and to draw easy, graceful, frictionless curves to facilitate the flow of air. While there are many styles of fittings which can be purchased, having single as well as double walls, it is to the advantage of the furnace man to understand the method of developing the various pattern shapes, a knowledge of which will enable him to lay out any required shape or size.

Conical Bonnets or Hoods

The first subject to be taken up will be development of the bonnet or hood. A good type of a bonnet is shown in Fig. 113 with a deep deflector. The method of developing the net patterns for the bonnet and deflector is shown in Fig. 114 and is accomplished as follows: Draw any vertical line as A B, upon which set off the vertical hight of the bonnet as X E, bearing in mind to make this 3 inches higher than the largest size leader pipe to be taken from it (to give room for dovetailing the collar.

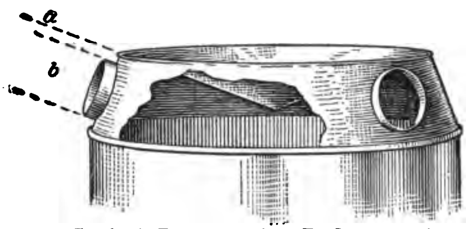


Fig. 113—Typical Conical Bonnet with Deflector which Determines the Angle of Collar.

Set off the half diameter of the casing as X C, also the half diameter of the top of the bonnet E G. Now extend C G until it intersects the center line at F. Using E as cented with radius equal to E G, draw the quarter circle G6, which divide into equal parts as shown. This quarter circle represents the plan on the line E G and would be the quarter pattern for a flat top casing minus the edges. Now using F as center with radii

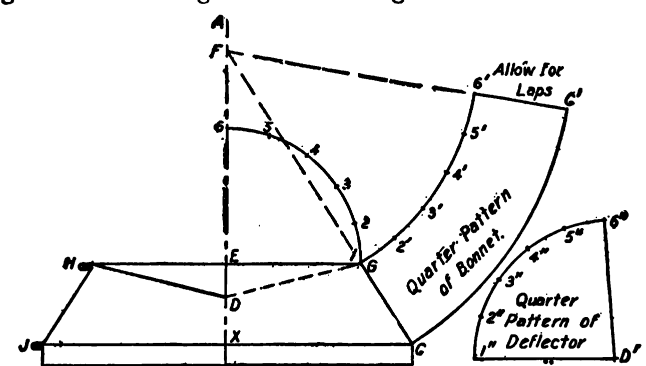


Fig. 114—Developing Patterns for Bonnet and Deflector.

equal to F G and F C, draw the arcs G 6′ and C C¹. On the arc G 6′ lay off the girth of the quarter circle as shown by similar numbers G to 6′. From the center F draw a line through 6′

intersecting the outer arc at C^1. Then will C C^1 6′ G be the quarter pattern for the bonnet, to which edges must be allowed for riveting and seaming. With radius equal to D. G, from D^1 as center, draw the arc 1″ 6″. Set off on the arc 1″ 6″ the girth of the quarter circle as shown, and draw the radial lines 1″ D^1 and 6″ D^1. This gives the quarter pattern minus the laps for the deflector.

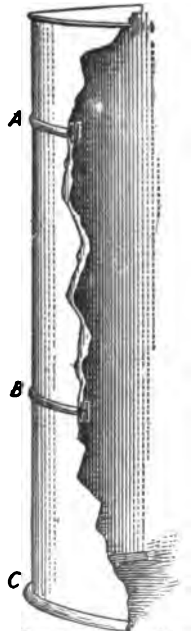


Fig. 115—Spacing the Casing Rings.

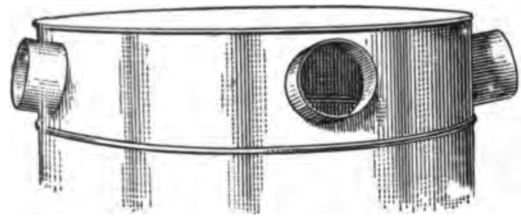


Fig. 116—Collars Joining a Straight Bonnet.

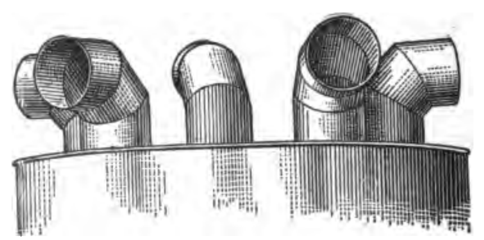


Fig. 117—Collars Joining a Flat Top Casing

The left half of the diagram is constructive, showing the seaming of the deflector to the bonnet at H, and the seaming of the bonnet to the casing collar at J. When laying out the various patterns we must consider the width of the iron being used, so as to cut without having much waste. The casing collar or rim C is usually made about 3 inhces wide so as to fit the casing ring. Another way is to allow about an inch lap along the curve C C^1 in the pattern and after the full bonnet has been riveted together, crimp the bottom edge on a crimper until it fits the casing ring snugly. The deflected part of the bonnet is usually filled with sand, but sometimes an additional sand ring is seamed to the top edge at H, making it about 2 inches high, placing a wire edge along the top. The above rule applies to any size or pitch of bonnet.

Furnace Casings

Casings should be double as indicated in Fig. 115 and care must be taken that the casing rings are so placed that stock widths of iron can be used. The rings A, B and C should be so placed that the distances between will allow using sheets either 24, 26, 28, 30 or 36 inches wide without waste. When the casing rings are not correctly placed, it necessitates using short pieces cut across the sheets, thereby using time and labor and wasting material, and does not make as neat an appearance, as when the sheets are rolled up lengthwise. The circumference of the casing is obtained by the use of a narrow strip of metal, passing it around the ring, holding it snugly, and then allowing edges for riveting or seaming.

Various Styles of Collars

There are three styles of collars usually employed, viz.: One joining a pitched bonnet, as shown in Fig. 113, another joining a straight bonnet as shown in Fig. 116, and the third joining a flat top casing as shown in Fig. 117. In developing the pattern for a collar joining a pitched bonnet, as shown in Fig. 113, the pitch of the collar *b* is usually made the same as the pitch of the deflector *a*, although this is not always done. Some mechanics do not develop the collar and opening in the bonnet by the geometrical rule, but roll up a piece of pipe and trim it to fit the bonnet at the desired angle and then mark off the opening on the bonnet and trim with the circular shears. While good results may be obtained in this manner, it is better to develop the patterns accurately, which can be saved for future use or be slightly modified for different construction.

Patterns for Collar on Pitched Bonnet

The method of developing the patterns for collars on pitched bonnets is shown in Fig. 118. First draw the center line X B, upon which establish the hight of the bonnet as C D. From C and D at right angles to X B draw the lines C 6 and D Y, equal respectively to the semi-diameters of the casing and top. Connect 6 with Y, extending the line until it meets the center line at X. Now with radius equal to C 6, from any point, as H, on the line X B, as center, draw the quarter plan, 6 V, as shown, and from H in plan draw H J, the center line of the collar. At the proper angle, draw the elevation of the collar, indicated by 1′ E F 5′ and in its proper position to the right as shown, draw the profile of the collar, which divide into equal spaces as shown from 1 to 5. With its center at *m* describe a half profile of the collar as shown in plan, dividing it as before, being careful in

numbering the spaces to see that the line 1 5 in the profile of the collar in elevation is perpendicular to the lines of the collar and parallel to the lines of the collar in plan, all as shown.

Divide part of the quadrant 6 V in plan in equal spaces as shown by points 6, 7 and 8, from which points draw radial lines to the center H. From the points 6, 7 and 8 erect vertical lines cutting the base line of the cone in elevation at 6, 7 and 8 of that view, from which points draw radial lines to the apex X.

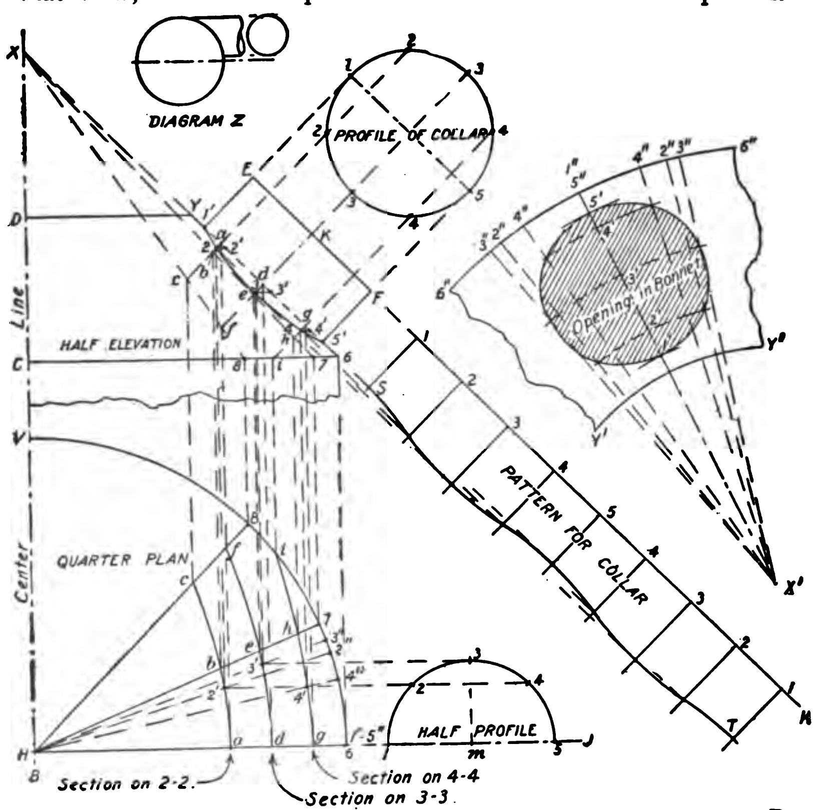


Fig. 118—Method of Obtaining Patterns for Collar and Opening to Be Cut in Pitched Bonnet.

Through the small figures 2, 3 and 4 in the profile of collar in elevation, draw lines at right angles to X 6 or E F cutting the radial lines in elevation. Where the line 2 2 cuts the radial lines drawn from 6, 7 and 8, at *a b* and *c*, drop vertical lines in the plan, until they intersect similar numbered radial lines 6, 7 and 8 in plan also shown by *a b* and *c*. A line traced through

these points will represent the partial section on the line 2 2 in elevation. In a similar manner where the planes 3 3 and 4 4 in elevation cut the radial lines 6, 7 and 8 at *d*, *e* and *f* and at *g*, *h* and the base line at *i*, drop vertical lines intersecting similar numbered lines in plan at *d*, *e* and *f*, also at *g*, *h* and *i*. The curved lines *d e f* and *g h i* represent the sections in plan on 3 3 and 4 4 in elevation. Through the points 2, 3 and 4 in the half profile in plan, draw horizontal lines intersecting the various section lines in plan, as shown at 2′, 3′ and 4′. From these intersections, vertical lines can now be erected cutting similar numbered section lines drawn through the elevation at 2, 3 and 4. A line traced these points as shown by 1′, 2, 3, 4 and 5′ will be the miter line between the collar and bonnet.

The pattern for the collar is now in order and is obtained by extending the line E F in elevation as F K, upon which the girth of the collar profile is placed as shown by similar numbers. Through these small figures, at right angles to F K, lines are drawn and intersected by lines drawn parallel to F K from corresponding numbered intersections 1′, 2, 3, 4 and 5′. Trace a line through points thus obtained, then will 1 S T 1 be the pattern for the collar, to which laps must be allowed for riveting and seaming.

The pattern for the opening in the bonnet is obtained as follows: From the intersections 2, 3 and 4 in the miter line in elevation, project horizontal lines to the right, intersecting the outline of the bonnet at 2′, 3′ and 4′. From X^1 in the diagram on the right as center with radii equal X Y, X 1′, X 2′, etc., of the elevation, draw short arcs as shown by similar numbers. From H in the plan, draw radial lines through the intersections 2′, 3′ and 4′ until they cut the base line as shown at 2″, 3″ and 4″. As 1′ and 5′ in elevation show the true points of intersections on the bonnet of lines from points bearing those numbers in the profile of the collar, these points will be shown at 1″ 5″ (point 6) on the base line. In the pattern for the opening in bonnet, establish at pleasure any line, as 1″ X^1 as a center line, and from the point 1″ set off either way on the arc 6″ 6″, the spaces indicated by the numbered points 4″, 2″ and 3″ in plan, as indicated by similar numbers in the pattern. From these points draw radial lines to X^1, intersecting arcs of similar numbers previously drawn. A line traced through points thus obtained will be the desired shape of the opening, which is shown shaded.

Should the collar be placed to one side of the center of the cone, that is axially oblique as shown in diagram Z at the top of the cut, the method of procedure will be precisely the same as that just described, except that the angle of projection upon the bonnet will be different.

Patterns for Collar on Straight Bonnet

Fig. 119 shows how the pattern for a collar on a straight bonnet and the opening in the side of the bonnet are obtained. The plan and elevation are clearly indicated, as is the method of obtaining the miter line from the plan after the proper pitch of the collar has been shown. It will be noticed that in the drawing the diameter of the collar is out of all proportion to the size

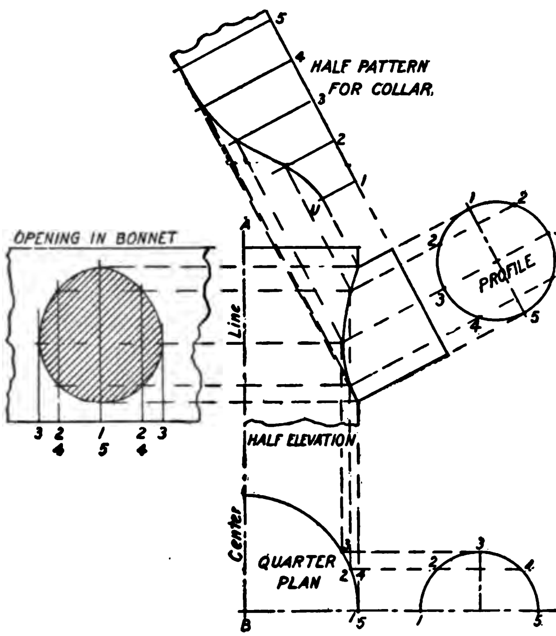


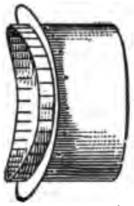
Fig. 119—Method of Obtaining Patterns for Collar and Opening to Be Cut on a Straight Bonnet.

of the bonnet. This has been done so as to clearly show how the points of intersection have been obtained. The method of obtaining the shape of the opening is so clearly shown at the left of the elevation, also that of the collar above, as to require no further description.

Fastening the Collars to the Bonnet

Figs. 120, 121 and 122 show how the collars are secured to the three styles of bonnets previously described. Fig. 120 shows a view of the finished collar ready to be secured to the pitched bonnet, which is constructed as shown in Fig. 121, where A shows the bonnet and B the collar. On the collar itself along the miter cut a half inch edge *a* is flanged out, then on the inside

a one and one-half inch strip is riveted as shown at *b*. The collar is inserted in the opening in the bonnet, and the notched flange turned snugly around as indicated at *c*, which secures the collar. If desired a few rivets can be placed in the flange *a*.



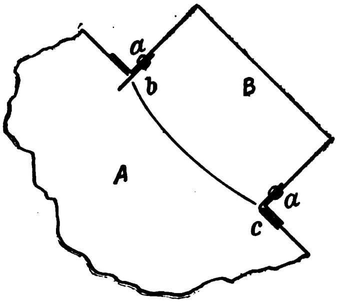


Fig. 121—Method of Securing Collar to Bonnet.

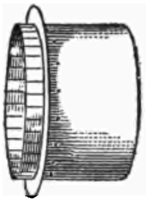


Fig. 120—Finished Collar for Pitched Bonnet.

Fig. 122—Finished Collar for Flat Casing Top.

The same method may be employed for the collars in the straight bonnet. Where elbows are connected direct to the flat top casing as shown in Fig. 117, the collars are prepared as shown in Fig. 122, and secured to the casing top as just described.

Elbows

When making the connections from the bonnet to the pipes, elbows are usually employed, and while adjustable elbows can be purchased from dealers, it is well to know the short rules for laying out the various pieced elbows, as odd sizes may be required, and elbows can be made up in spare time. Fig. 123 shows the various positions to which a four pieced elbow of this type can be adjusted to suit any condition which may arise.

When patterns for elbows are to be laid out, a short method can be employed for finding the rise of the miter line by means of a protractor, as shown in Fig. 124. This rule is applicable to any size elbow no matter how many pieces it contains or what angle it is intended to have when completed. For an example, we will assume that the rise of the miter line is to be found for a four piece elbow, whose throat is to be 8 inches, its diameter 6 inches and whose angle is to be 90 degrees when completed. In diagraming all pieced elbows, each end piece counts one as a unit of degrees and each middle piece counts as two. Thus in a four pieced elbow we have $1+2+2+1=6$. Six is then the divisor. As the completed elbow is to have 90 degrees when completed, the rise or the degree of the miter line is found by

to make the work substantial. For example, the voids in sand are filled with cement and this mixture is used to fill the voids in gravel or broken rock.

The ability to judge by sight or determine by test the proportions of materials for a cement mixture is gained only through long experience, and it is essential that the mixture be right for the work in hand. A certain mixture for a foundation pit or duct in a cellar which is always dry would not do for building a foundation pit or duct, which of necessity must be watertight on account of a cellar being wet at certain periods of the year, nor would a mixture suitable for building a sidewalk be right for use in constructing a cistern.

Concrete mixtures are classified in two different ways. First as to richness, meaning the quantity of cement used, and secondly as to consistency or wetness.

When so classified a cement mixture is known as rich, medium, ordinary and lean. A 1 :2 :4 mixture would be called a rich mixture. The formula 1 :2 :4 indicates one barrel of cement (four bags to the barrel) to two barrels of sand, and four barrels of gravel or broken stone or other coarse aggregates.

A 1 :2.5 :5 mixture is one barrel of cement, two and one-half barrels of sand and five barrels of broken stone or loose gravel, and this combination of materials would be classified as a "medium" mixture.

A 1 :3 :6 mixture measured in like manner is known as an "ordinary" mixture, and a 1 :4 :8 combination of cement, sand and gravel as a "lean" mixture.

In consistency the mixture may be "very wet," "medium wet" or "dry," the amount of moisture necessary depending upon the work for which it is intended.

For use in building foundations and ducts for furnace work a "medium" or "ordinary" mixture "medium wet" is desirable, provided the pit or duct is not to be waterproof. If the pit or duct must be waterproof on account of a wet basement, or trouble at certain periods from surface water, the mixture should be a 1 :2 :4 (rich) or a 1 :2.5 :5 (medium), and in consistency, medium to very wet.

Mixing Concrete

There are several methods of mixing the concrete. The sand and cement may be mixed dry, and this mixture spread layer upon layer upon the broken stone, gravel or aggregate before the water is added, or the sand and cement may first be mixed with water into a mortar, and this mortar then mixed with the

broken stone or gravel, after which, in either case, it should be turned with a shovel until a thorough mixture of the ingredients is obtained, or until all particles of the aggregates are thoroughly coated with the cement paste.

There are several kinds of cement to be had, the best for general use being that called Portland.

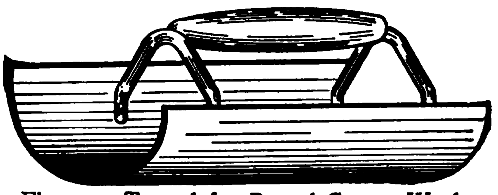


Fig. 109—Trowel for Round Corner Work.

Portland cement consists principally of limestone and slag crushed separately and dried to remove all moisture, after which each ingredient is ground extremely fine. After being combined in a certain proportion this mixture is calcined or burned to a clinker. This clinker is then cooled, pulverized fine, and mixed with a certain quantity of gypsum, when it is ready for the storehouse, where it is kept free from moisture until shipped or supplied for use.

The Tools

For use in constructing cement ducts, pits and other work of like character, but very few tools are required and these are inexpensive.

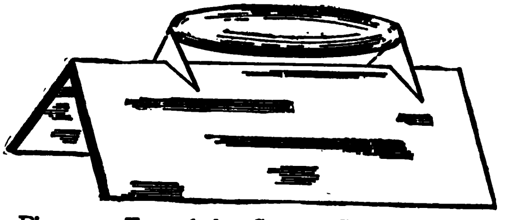


Fig. 110—Trowel for Square Corner Work.

Other than a shovel, hoe and ordinary trowel there are a few tools which are useful and convenient. Fig. 109 illustrates a smoothing trowel for round corner work. Fig. 110 a smoothing trowel for square corners. Fig. 111 another form of a round corner smoothing trowel. Fig. 112 shows two forms of a tamper (a tool for tamping or pounding the cement mixture to remove the voids), which may be made from any heavy iron casting planed smooth on the lower side and to which a handle may

to make the work substantial. For example, the voids in sand are filled with cement and this mixture is used to fill the voids in gravel or broken rock.

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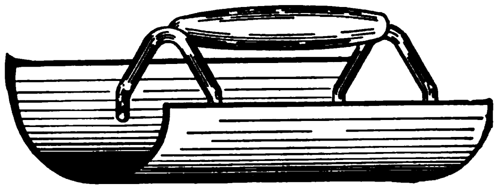

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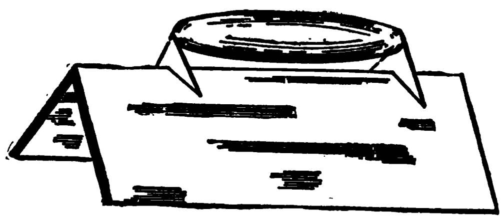

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Fig. 131, when the method of procedure is the same as before with only the difference in the position of the profile C from that of H in Fig. 129. The former produces an elbow on the "sharp" and the latter an elbow on the "flat."

Developing the Patterns for a Reducing Elbow

Fig. 132 shows a view of a three pieced 90 degree reducing elbow in which the pipe A is reduced by means of the transition piece C to the required size B. In working out this problem the pipes A and B are developed by means of parallel lines, while the middle transition C is developed by triangulation. How these three patterns are aid out is shown in detail in Fig. 133. First draw the center line of the elbow as shown by *a* 3 8 *b*, making the distance 3 8, twice that of *a* 3 or 8 *b*.L Extend 3 *a* and 8 *b* indefinitely as shown, upon which establish the centers *i* and *k* respectively and describe the profile of the small pipe F and large pipe E. at sufficient distances from *a* and *b* of both arms of the elbow. Obtain the miter lines of the elbow by using 3 and 8 on the center line as centers and describe the arcs *c d* and *f g* respectively. Now, with any desired greater radius and using *c* and *d*, also *f* and *g* as centers, describe arcs intersecting each other at *e* and at *h*. Draw lines indefinitely through *e* 3 and *h* 8. Intersect the former by horizontal lines drawn through 1 and 5 in the profile F, and the latter by vertical lines drawn through 6 and 10 in the profile E. Connect 1 with 10 and 5 with 6 to form the middle piece B. Then A B C shows the side elevation of the reducing elbow.

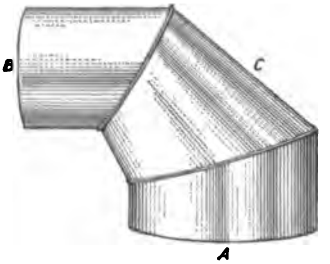

Fig. 132—A Reducing Elbow.

Divide both the half profiles F and E in the same number of equal parts, as shown from 1 to 5 and 6 to 10 respectively, and from these various small figures draw lines parallel to the center lines of the pipe until they intersect the miter lines as shown by simliar numbers. The half patterns for the pipes A and C are developed in the usual manner as shown and need no further explanation.

The pattern for the middle section C will be laid out by triangulation. No sections need be developed on the miter lines 1 5 or 6 10 in elevation, as correct measurements for the several spaces can be taken from the miter cuts 1′ 5′ and 6′ 10′ in the patterns. Connect points in 1 5 with those in 6 10 as shown

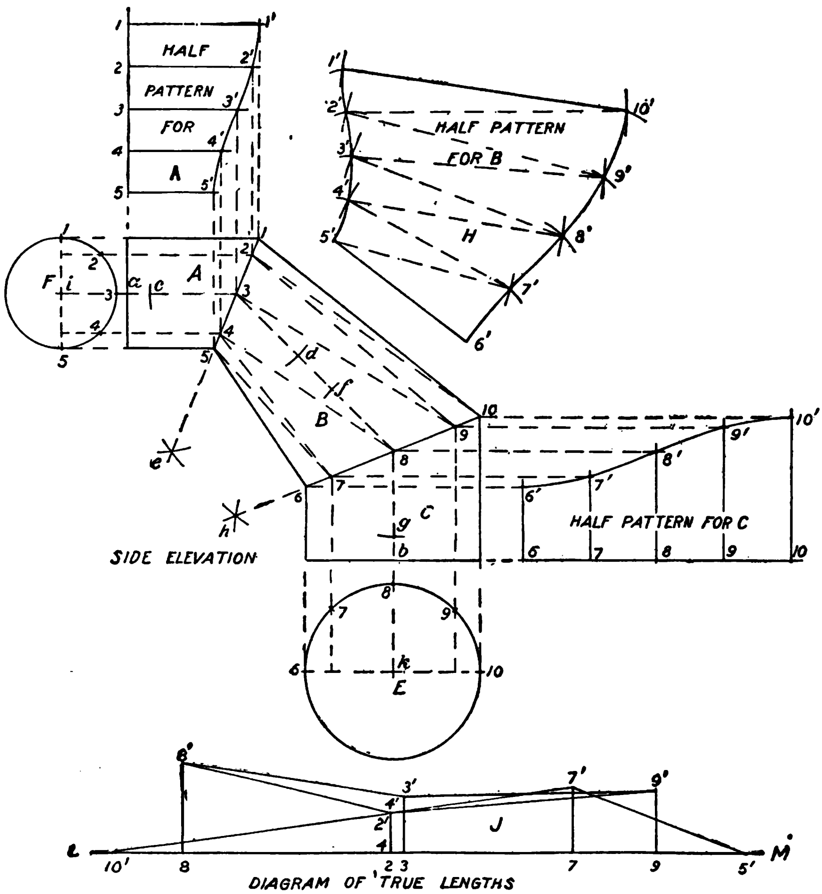

Fig. 133—Developing the Patterns for a Pieced Reducing Elbow.

by the dotted lines. These lines then represent the bases of sections at each end of which prpendiculars will be erected whose altitudes will equal the various hight in the semi-profiles F and E as shown in diagram J. For example, to find the true length of the line 4 8 in B, set off its length as shown from 4 to 8 on

any horizontal line as L M in J, and at 4 and 8 erect the perpendiculars 4 4′ and 8 8′ equal respectively to the distances measured from the center lines to points 4 and 8 in the profiles F and E. The distance from 4′ to 8′ in J shows the required length. In a similar manner are the remainder of true lengths found.

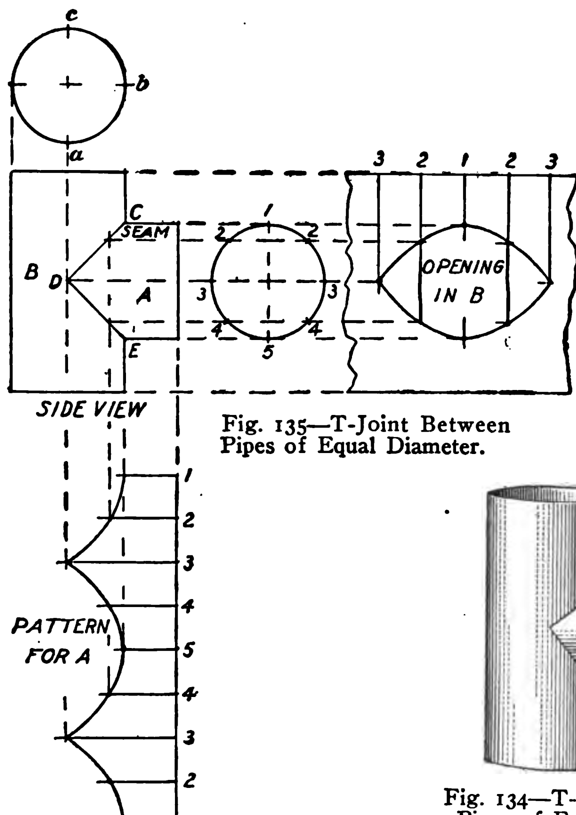

Fig. 135—T-Joint Between Pipes of Equal Diameter.

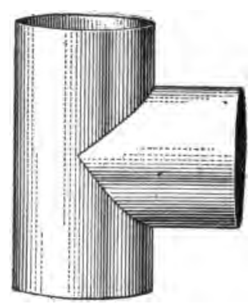

Fig. 134—T-Joint Between Pipes of Equal Diameter.

The pattern is next in order. As 5 6 in B shows its true length, set off this distance as shown by 5′ 6′ in the pattern at H. Now with radius equal to 6′ 7′ in the half pattern for C, and with 6′ in H as center, describe the arc near 7′, which intersect by an arc struck from 5′ as center and 5′ 7′ in the true lengths in J as radius, now with 5′ in the pattern H as center and 5′ 4′ in the pattern A as radius describe the arc shown near 4′, which intersect by an arc struck from 7′ as center with 7′ 4′ in the diagram J as radius. Proceed in this manner, using alternately, first one of the spaces along the miter

cut in half pattern for C, with the proper true length in J to form the larger end of the pattern; then one of the spaces along the miter cut in the half pattern for A with the proper length in

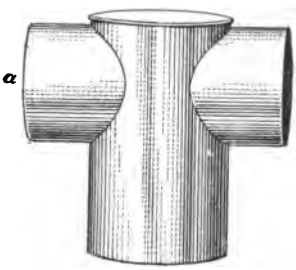

Fig. 136—A Round Header.

J to form the smaller end of the pattern, until all spaces have been used and the pattern has been developed. Laps must be allowed for seaming as before explained.

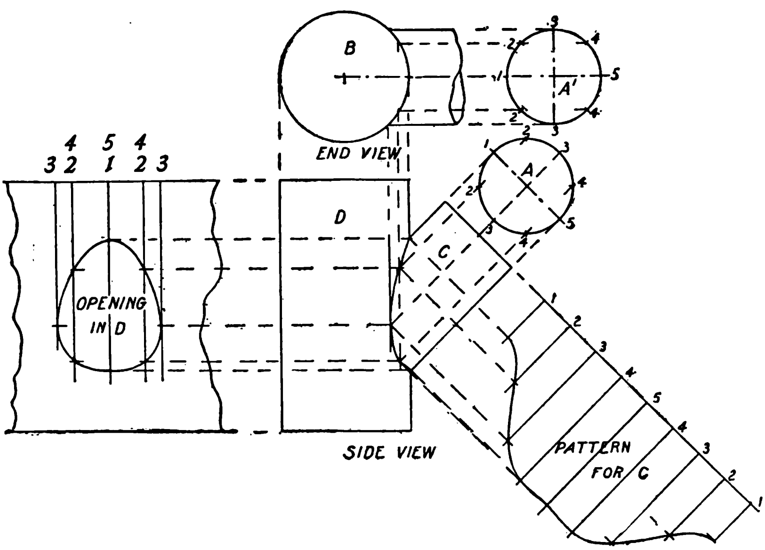

Fig. 137—Patterns for T-Joint Between Pipes of Unequal Diameters at Other Than a Right Angle.

Fig. 134 shows a view of a T joint where the three openings have equal diameters. The rule employed for developing the patterns is explained in connection with Fig. 135, in which an elevation of the joint is shown. When the sizes of the two

branches are the same, no projections of points are required in finding the miter line; all that is required is to intersect the centers of the two branches as at D and then draw the miter lines C D E. The pattern for the branch A is obtained in the usual manner. The girth of A is placed at right angles to the lines of the pipe as shown, the usual measuring lines drawn and intersected as shown resulting in the pattern for A.

The shape of the opening to be cut in the main pipe B is obtained by taking one half of the girth of pipe as indicated by *a b c* (or 3 to 1 to 3 in the profile for A, since both pipes are similar) and placing it at right angles to B as shown, and then intersecting the measuring lines from the divisions in the profile, all as shown. This short method can only be followed when the two branches have the same diameters. Fig. 136 shows a round header with lead off collars at *a* and *b*. The principles shown in Fig. 135 can be applied to Fig. 136.

T Joint Between Pipes of Unequal Diameters at an Angle

When a branch is to be taken from a main pipe at an angle, the branch being of smaller diameter than the main, the rule to follow regardless of what the diameters or angle may be, is shown in Fig. 137 in which A and A^1 show the profile of the branch pipe and B the profile of the main. D C shows the side view of the T, the branch C in this case being placed at an angle of 45 degrees. First divide both profiles A and A^1 into the same number of equal parts, placing the numbers in the position shown. From the points in A^1 draw lines parallel to the lines of the pipe until they intersect the profile of the main pipe as shown, from which vertical lines are drawn and intersected by lines drawn parallel to the pipe C from the numbered points in the profile A. Through the intersection thus obtained trace the miter line shown. The pattern for the branch C is obtained in the usual manner as indicated. To obtain the opening in the main pipe D, obtain the girth by using the various spaces in the end view B, measuring each space separately, as they are unequal, and place them at right angles to the line of the main pipe D in the side view. The usual measuring lines are now drawn, and intersected by lines from points of corresponding number shown in the miter line. This gives the opening to be cut in the pipe D.

In Fig. 138 is shown a view of a reducing T joint such as is sometimes used in trunk lines of heating. The method of laying out these patterns is shown in detail in Fig. 139. First of the illustration, and place on either side of the center line A B, the widths *a* 1′ and *b* 1 in their proper positions connect the

lines 1′ 1 extending them until they meet at C. On the line 1 1 place the semi-profile H, which divide in equal spaces as shown from 1 to 3, from which points draw lines parallel to A B intersecting the line 1 1. From the apex C draw radial lines

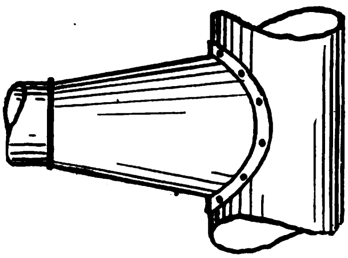

Fig. 138—A Reducing T-Joint.

through the points on 1 1 until they intersect the profile of the large pipe from 1′ to 3′. From these intersections at right angles to A B draw lines cutting the side of the tapering pipe at 1′ 2″ and 3″. These points are used in developing the pattern for the taper joint in the following manner: Using C as center and C 1 as radius, draw the arc 1 3″ ′, upon which lay off the girth of twice the semi-circle H as shown by similar numbers. Through these small figures draw radial lines from C, extending them indefinitely and intersecting them by arcs of corresponding number struck from C as center with radii equal to C 1′, C 2″ and C 3″. A line traced through points thus obtained as shown by J K L, together with 3″′ 3″ will give the net pattern, to which edges must be allowed for riveting.

The shape of the opening to be cut in the cylinder is obtained from the side view, which is projected as follows: Draw any horizontal line as D E, upon which locate the points C^1, *b*′ and 1 from similar points in the end view. Draw the semi-profile H^1 and divide similar to H, reversing the numbers as shown. From the small figures in H^1 draw perpendiculars to 3 3 intersecting that line. Through the points on 3 3 draw radial lines from C^1, extending them to intersecting lines drawn at right angles to A B from the similar numbered intersections 1′ 2′ and 3′ in the end view of large pipe, which gives the miter line in the side view. Now upon any line, as F G drawn at right angles to the line of the main pipe, place the girth of large pipe as obtained from the various divisions 1′ 2′ 3′, etc., in the end view, being careful to measure each space separately, as they are all

unequal. From the points thus obtained on F G draw measuring lines at right angles to F G, and intersect them by lines drawn parallel to F G from similar points in the miter line. The shaded portion shows the opening to be cut in the main pipe.

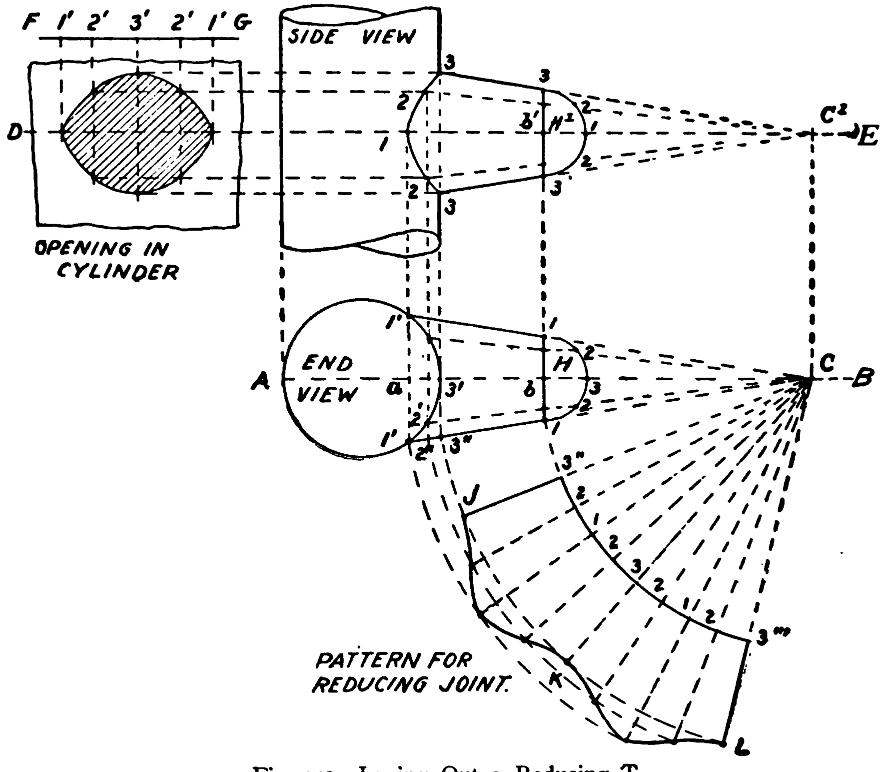

Fig. 139—Laying Out a Reducing T.

Construction of Riveted Joints in Tees

The method of constructing the joints shown in Figs. 134, 135, 136 and 138 is explained in Fig. 140, which shows how the T is riveted to the main pipe. A flange *a* in the diagram is turned outside on the main pipe, while *b* shows the flange turned outward on the T through which the rivets are placed, giving an appearance similar to Fig. 138.

Construction of Cold Air Shoes

When making the cold air connection to the bottom of the furnace a shoe is required. Two styles of cold air shoes for

connections to round pipe are shown in Fig. 141. The first, A, is beveled, while B is made tapering to suit the round pipe. The round collar joining the shoe is constructed similar to Fig. 122, but the connection of the shoes in Fig. 141 with the furnace is

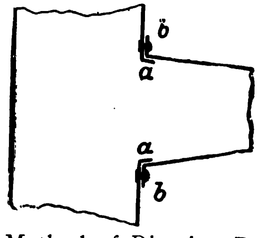

Fig. 140—Method of Riveting Reducing T.

prepared as there shown, in which *a* in both views indicates the flange on the shoe proper, and *b* is a separate flange riveted to the inside of the shoe and notched so as to allow it to be bent inward on the casing. The shoe A is shown in position on a furnace in Fig. 142, where the round cold air pipe is also connected.

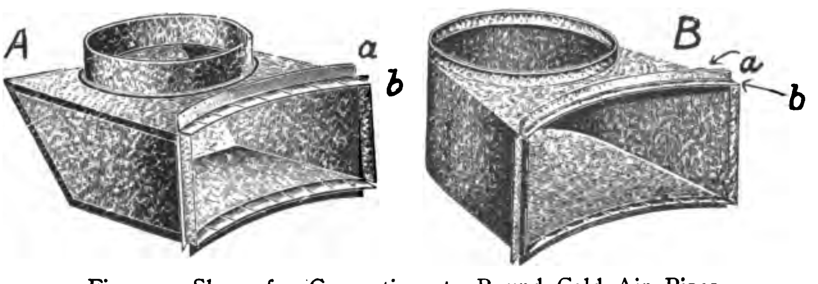

Fig. 141—Shoes for Connections to Round Cold Air Pipes.

In Fig. 143 is shown a cold air shoe for inside air connection. A is the collar for the hall connection. A wire mesh is placed in the opening through which the inside basement air is admitted. Flanges are placed at *a a* for casing connections. In making up these shoes the corners are double seamed and the curve at the farther end of the shoe suits the curvature of the furnace casings.

Fig. 144 shows a galvanized sheet metal shoe for rectangular pipe. In placing the collars or shoes on the casing they must always be put on before the casing is put around the furnace. A in Fig. 145 shows the shoe in position for rectangular cold air duct, the method of fastening to the casing being indicated

in diagram X, in which A represents the casing and B the base ring. The outerflange of the shoe collar is placed snugly against the casing and the inner notched flange *a* turned tightly against

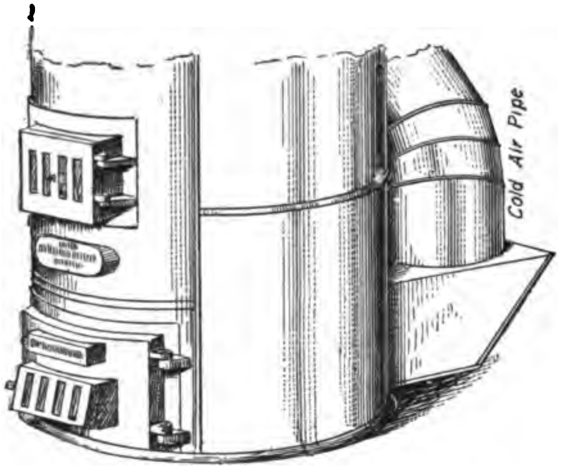

Fig. 142—Shoe Connected to Round Cold Air Pipe.

the inside of the casing, as shown at *b*, and riveted. Sometimes a cast iron shoe is riveted or bolted to the casing proper, as shown in Fig. 146, holes being drilled along the cast iron flange to which the cold air duct is bolted.

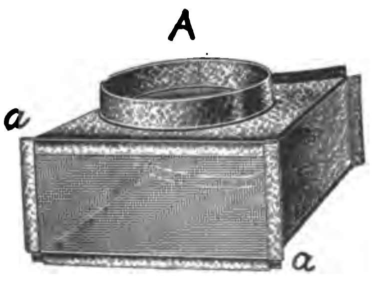

Fig. 143—Cold Air Shoe for Inside Air Connection.

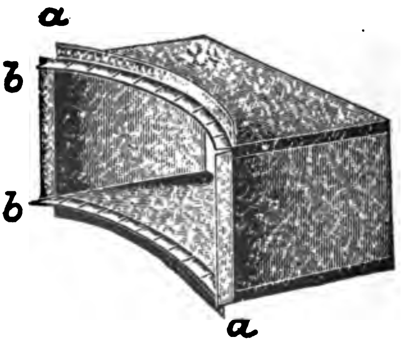

Fig. 144—Sheet Metal Cold Air Shoe for Rectangular Pipe.

Pattern for Shoe Connecting to Center of Furnace

When the cold air shoe is directed toward the center of the furnace, the pattern for same can be laid out as shown in Fig.

147, in which A shows the plan view of the furnace, whose radius is D. B shows the plan of the duct whose section is shown at C. Take the girth of the duct C, from 1 to 2 to 3 to 4 to 1 and set it off on any horizontal line as shown just below. Make the length of the collar as desired, as 1 *a*, and through *a*

Fig. 145—Connecting Sheet Metal Shoe to Furnace Casing.

draw the line E F, parallel to 1-1. Through the points 2, 3 and 4 draw lines intersecting E F at *a*, *b* and *b*. Using D as radius, and *a* and *b* on both sides of the diagram as centers, describe arcs intersecting each other in *c*. With the same radius and *c* and *c* as centers draw the arcs *a b* and *b a*, which complete the pattern or layout. When the duct is of such size that

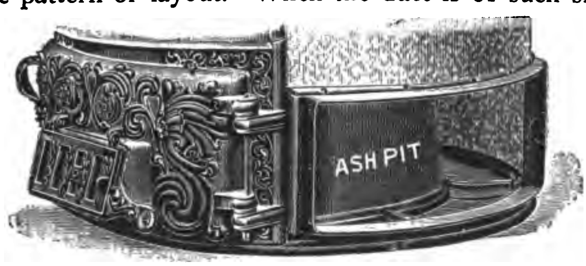

Fig. 146—Cast Iron Shoe for Cold Air Connection.

it cannot be made up of one piece the corners are then double seamed, making it up in either two or four pieces.

Pattern for Shoe Connecting to One Side of Furnace

When the cold air duct connects to the casing to one side or off the center, as shown in plan in Fig. 148, the layout or pattern is obtained as just below. In the cut A is the furnace, B the duct or shoe, and C its section. Take the girth of C as before and place it on any straight line, as shown below, and at the desired distance draw any line as E F. At right angle to the duct line, from the intersection with the casing at B, draw the

line B *a*. Take the distance from *a* to *b*, which represents the corners 3 and 4 in the section, and set it off on lines drawn

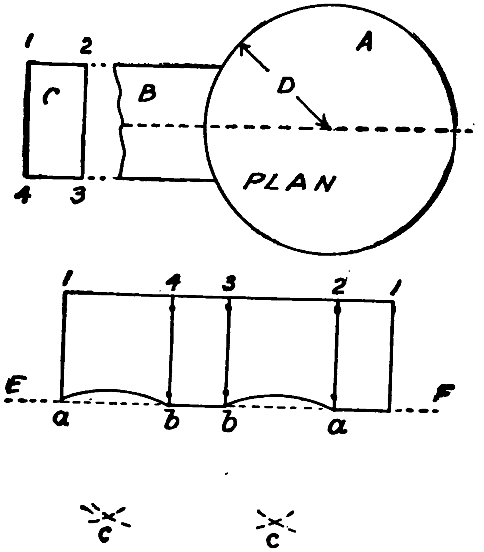

Fig. 147—Layout of Shoe for Concentric Cold Air Pipe.

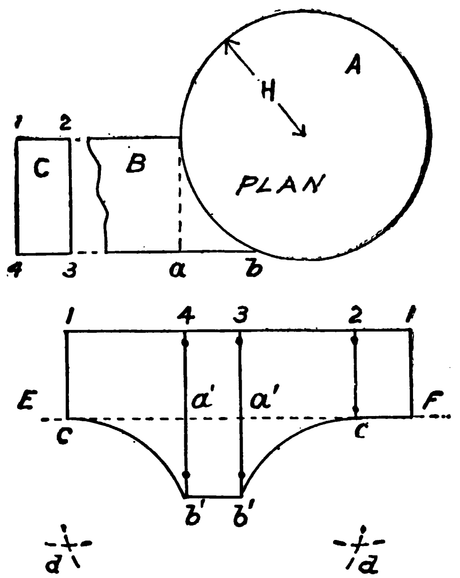

Fig. 148—Layout of Shoe for Excentric Cold Air Pipe.

through 3 and 4, measuring from the line E F, as shown from a' to b'. Now using the proper radius H, and b' and c in the layout as centers, intersect arcs at d. Then using d and d as centers with the same radius, describe the arcs c b' as shown. This gives the layout for a duct, intersecting the shoe or casing as shown in plan. Flanges must be ollowed for riveting and seaming.

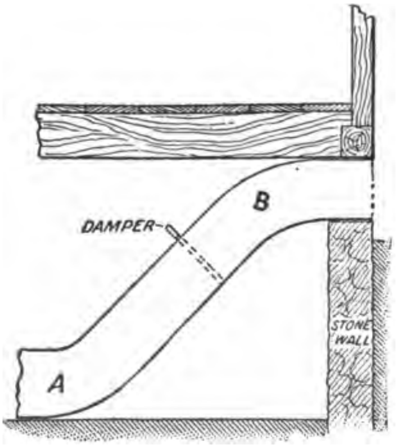

Fig. 149—Showing How Friction Is Avoided.

Frictionless Cold Air Duct Elbows

When connecting the outside cold air duct all possible friction should be eliminated. All elbows and bends should be curved as shown by A and B in Fig. 149. A general rule which can be employed in obtaining the radius for describing the throats

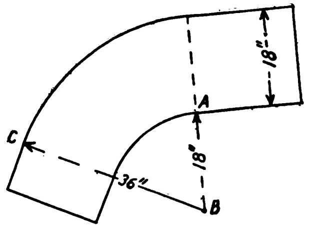

Fig. 150—Rule for Obtaining Radii for Curves.

of the elbows or bends is shown in Fig. 150. Whatever the width of the pipe may be, that width should be the radius with

which to describe the throat of the bend as shown by B A. To this radius is added the width of the pipe which gives the radius B C for describing the heel C. If the width of the duct is 18 inches, the radius of the throat becomes 18 in. and that of the heel 36 in.

Seaming Cold Air Duct Elbows

There are two methods of seaming the corners of the elbows in cold air duct work; the first method is shown by A in Fig. 151, in which the top and bottom of the elbows have a formation

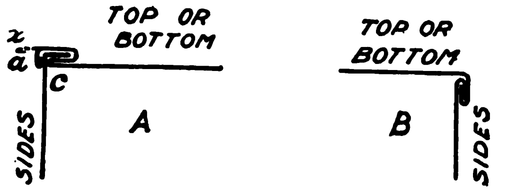

Fig. 151—Seaming the Cold Air Duct Elbows.

as indicated by *c*, while the sides or elbow curves have a single edge. The lock is first bent as indicated by *x*, and after the sides are inserted in the groove a "dolly" is held on the inside

Fig. 152—Floor Register Box.

corner *c* and *x* turned down with the mallet as indicated by *a*. The second method B is the regulation method but requires more time than the former.

Developing and Constructing Floor Register Boxes

Register boxes are constructed of single and double walls. Those usually employed are of the single wall type shown in Fig. 152, and are made in various sizes. The size of the register box is determined by the size of pipe to which it will be connected. Floor registers are usually connected to round pipes. To find the proper size box from the round pipe, the following rule is usually employed:

Rule for Determining the Size of the Register Box

Find the area of the given round pipe; then double it and find the stock size of register near to this area, and make register box to fit. For example, if the round pipe is 10 inches, its area is 78.54, which doubled gives 157.08. The nearest stock size register is 10" × 16", which equals 160, then 10⅛" × 16⅛" is the proper size register box to use. The one-eighth inch added to the size of the register is for play room.

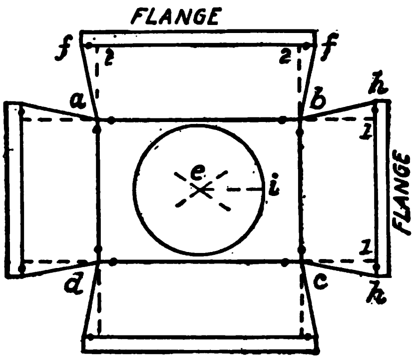

Fig. 153—Net Patterns for Floor Register Box in One Piece.

Table of Areas of Round Pipes and Registers

The following table gives a safe guide to determine the correct sizes of registers to use with the standard sizes of round pipes:

TABLE OF AREAS OF ROUND PIPES AND REGISTERS.

Dimensions of pipe.	Area in square inches.	Size of register required.
8"	50	8×12
9"	63	9×14
10"	78	10×16
12"	113	14×16
14"	154	16×20
16"	201	18×24
18"	254	20×26
20"	314	24×27
22"	380	24×32
24"	452	30×30

Pattern for Floor Register Box in One Piece

Fig. 153 shows how a floor register box is developed in one piece when it is of such size that it can be made from one sheet of tin plate. In laying out register boxes, a slight taper should be given as shown in Fig. 152. In Fig. 153 the method of developing the box is as follows: Draw the required size of the rectangle *a b c d* and draw the two diagonal lines intersecting each other at *e*, which is the center point with which to describe the opening to receive the collar. Parallel to the sides of the rectangle, place the hight of the box as shown, to which allow a flange. Extend the sides and ends of the box and allow the taper as indicated by 1 *h* and 2 *f* and draw the miter lines to the corners *a b c* and *d*. Edges must be allowed for double seaming.

Patterns for Floor Register Box in Four Pieces

When the register box is of a large size the register box can be made up in four pieces as indicated in Fig. 154, where *a b*

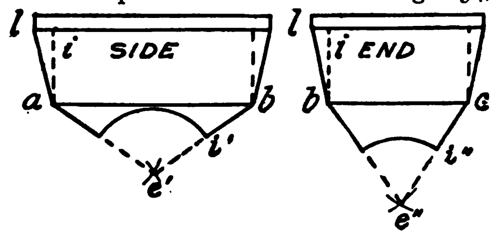

Fig. 154—Net Patterns for Floor Register Box in Four Pieces.

and *b c* show respectively the length and width of the register, while *a i* and *b i* show the hight of the sides, the flare being indicated by *i l*. To obtain the bottom of the box on each quarter pattern, a rectangular bottom should be drawn on the bench or elsewhere, of the desired size or as long as *a b* and as wide as *b c* similar to *a b c d* in Fig. 153. Then with a radius equal to *b e* and using *a, b, b* and *c* in Fig. 154 as centers, describe arcs, cutting each other at e' and e''. Then using *e i* in Fig. 153 as radius and e' and e'' in Fig. 154 as centers draw the arcs i' and i'' as shown, which intersect by the diagonals drawn from *a* and *b* to the center e' and from *b* and *c* to the center e''. Edges must be allowed for double seaming the corners and bottom. Sometimes, however, the boxes are made in five pieces—that is, the four sides and a separate bottom.

Quick Method of Joining Collar to Register Box

When the corners of the register box shown in Fig. 153 have been doubled seamed, the collar can be joined to the bottom

by a quick method as shown in Fig. 155, in which the collar is beaded about one-half inch below the end, using a quarter inch

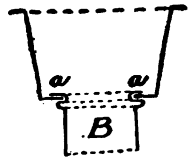

Fig. 155—Two Methods of Joining Pipe Collar to Register Box.

bead. The half-inch flange above the bead is now notched about every inch, after which the collar is placed through the bottom

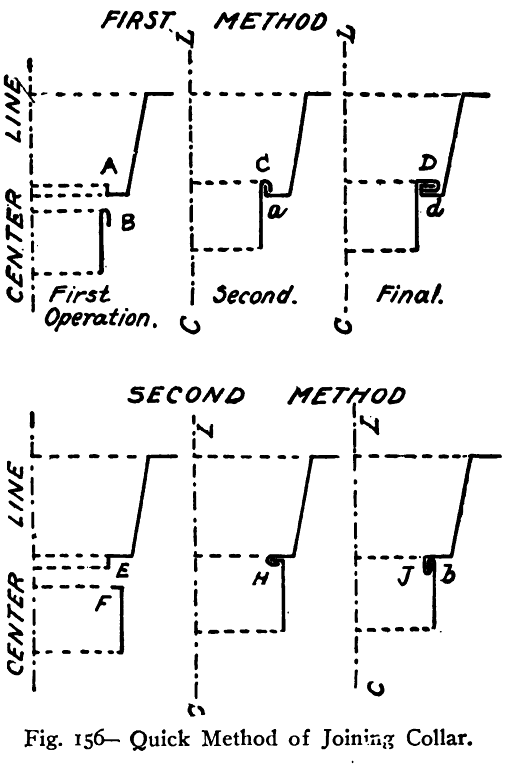

Fig. 156— Quick Method of Joining Collar.

of the register box, as at B, then pressing the bead tightly against the bottom of the box, the notched flanges are turned down firmly as at *a a*.

Two Other Methods of Constructing Register Boxes

In Fig. 156 are shown two other methods of joining the collar to the boxes, each method being shown in three operations. In the first method A shows a section of a register box with the edge A turned up around the circular opening in the square bottom. On the collar B an edge is turned outward on the burring machine as shown. This collar B is then slipped over the edge A, as shown in the second operation, the lock closed with the flat plyers. The box is now set on the square head stake at *a* and double seamed with a mallat as shown by *d* in the final method. The first operation of the second method an edge is turned downward around the circular opening in the flat bottom, and F shows an edge turned inward around the collar. The collar is now placed inside of the edge E and E turned over as shown at H in the second operation. The lock is then turned down and double seamed as shown at *b* in the third operation.

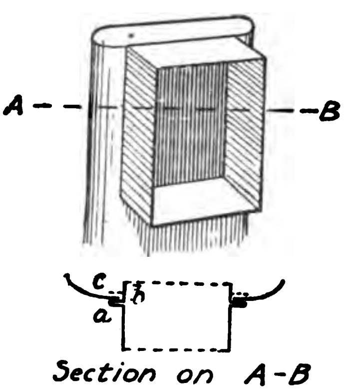

Fig. 157—Construction of Combination Header and Register Box.

Construction of Combination Header and Register Box

In the upper part of Fig. 157 is shown a view of a combination header and register box. The register box is joined to the headed oval stack as shown, the box collar being of sufficient depth to run flush with the finished plaster line of the partition. The method of joining the collar to the stack is shown in the cut below which represents a section through A B. Note that the collar has a doubled flange at *a*, also a projecting flange *b*. The stack is cut out to the required size, the collar inserted and *b* turned over as indicated by *c*.

Boots or Wall Pipe Starters

Wall pipe starters are known in some shops as "boots" or "shoes." Fig. 158 shows a box-shaped starter connecting to two registers. There are various styles of starters but those most generally used on first class jobs are known as "box shaped" and "frictionless." Care should be taken in designing the starter

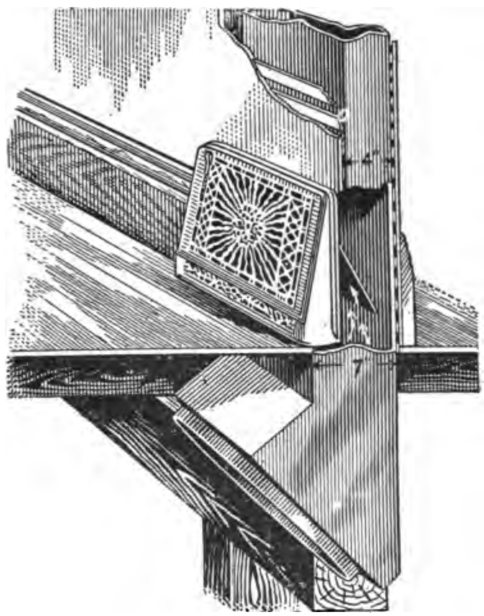

Fig. 158—Box-Shaped Starter Connecting to Two Registers.

previous to developing the patterns, that easy, graceful sweeps are obtained to facilitate the flow of air and avoid friction. Fig. 159 shows nine styles of box shaped starters which cover designs for almost any case that may arise. In making up these styles of starters the pattern shape is pricked direct from the drawing and edges allowed for double seaming, the round collars being attached as shown in a previous article. A frictionless round to "oval" starter is shown in Fig. 160. This same style of frictionless starter is also made up for rectangular risers instead of "oval," as will be explained.

Developing the Pattern for a Round to "Oval" Frictionless Starter

The method used for laying out the pattern for the round to oval starter is shown simplified in Fig. 161. According to this method the lines of the elevation are used as base lines and the

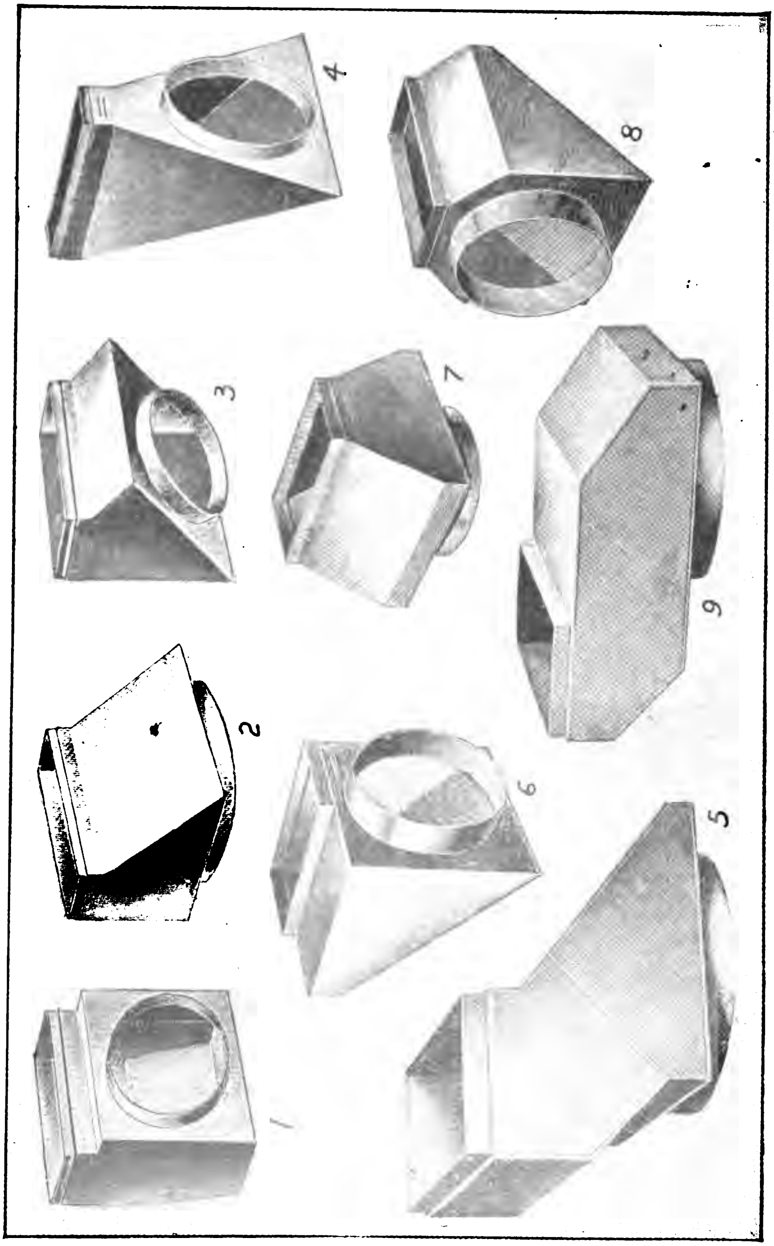

Fig. 159—Nine Styles of Box-Shaped Starters.

various heighths in the semi-profiles as altitudes, when fiinding the true lengths. The first step is to draw the elevation of the starter or boot as shown by 3, 4, 4″, 3″, on either end of which place the semi-profiles of the round and oval or oblong pipes as shown. As both halves of the starter are alike it is only necessary to

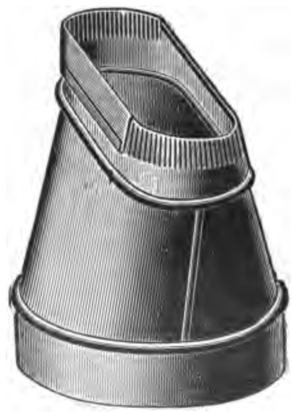

Fig. 160—Round to Oval Frictionless Starter.

develop one-half and duplicate it. The shaded sections in the drawing show the half profiles. In dividing the half profiles in practice more spaces must be used than are shown. In this case the upper and lower quadrants have been divided into two spaces each, as shown by the small figures 1 to 3 and 4 to 6. From these small figures 1 to 3 at right angles to 3 3″ and from points 4 to 6 at right angles to 4 4″, lines are drawn intersecting the lines 3-3″ at 1′ 2′ and 4 4″ at 5′ 6′. Connect these intersections by lines 6′ to 1′ to 5′ to 2′ and to 4, which lines will represent the bases of sections to be constructed, whose altitudes are equal to the various hights of points of corresponding number in the semi-profiles. Take the various lengths in elevation from 6′ to 1′, bases 1′ to 5′, 5′ to 2′ and 2′ to 4 and set them off as shown by corresponding numbers on the horizontal line A B. From these points erect lines equal in hight to the corresponding altitudes in the semi-profiles. As point 4 in the semi-profile has no hight over the base line 4-4″, then 4 remains on the line A B. Connect the various points thus set off, which will show the true lengths desired. As the seam is usually placed along the ends 3-4 and 3″-4″ in elevation, the half pattern can be developed as follows: Draw any straight line 1 1 in the pattern equal to 1 1″ in the elevation; then using 1-6 in the true length as radius, and 1 and 1 in the pattern as centers describe arcs intersecting each

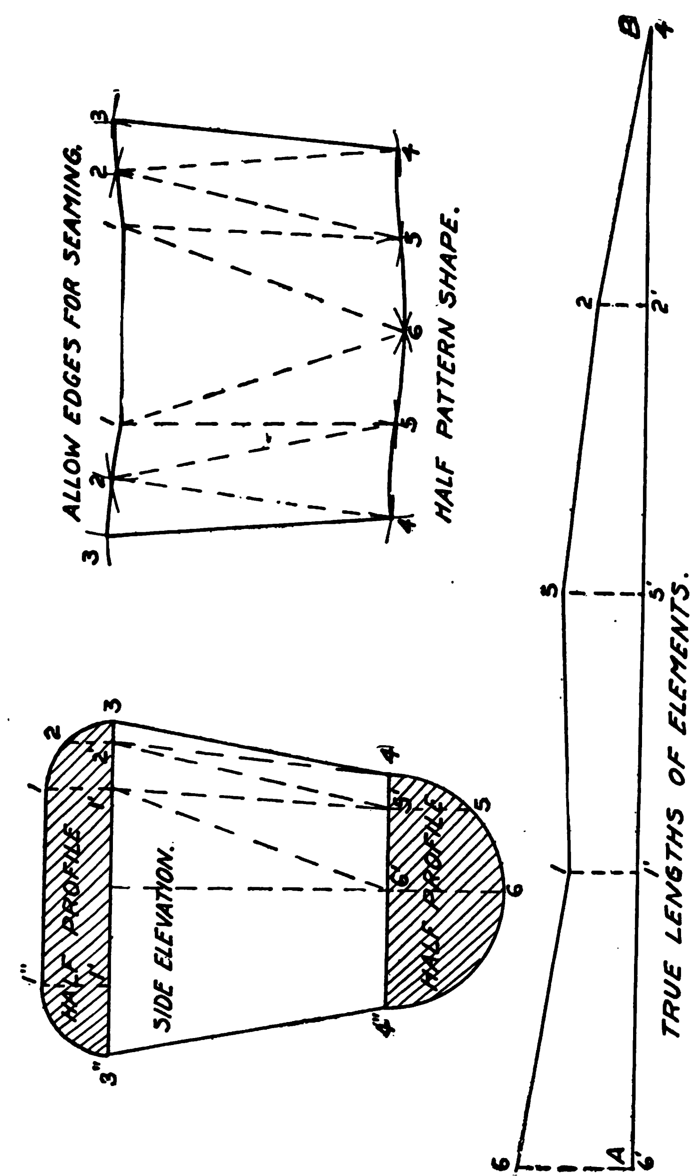

Fig. 161—Method of Developing the Starter Shown in Fig. 160.

other at 6. With 6 5 in the semi-profile as radius and 6 in the pattern as center, describe the arcs on both sides at 5 and 5 of the pattern which intersect by arcs struck from 1 as centers and 1 5 in the true lengths as radius. With 1 2 in the semi-profile as radius and 1 and 1 in the pattern as centers, describe the arcs 2 and 2, which intersect by arcs struck from 5 and 5 as centers and 5 2 in the true lengths as radius. Proceed in this manner, using alternately, first the division in the round profile, then the proper true length; the division in the oval profile, then again the proper true length, until the line 3 4 in the pattern has been obtained, which equals 3 4 in elevation, its true length. Trace a line through points thus obtained in the pattern which will give the layout for the half pattern, to which edges must be allowed for seaming purposes.

Various Styles of Frictionless Starters

Fig. 162 shows five styles of frictionless starters which can be used for any condition which may arise. The principles to be used in developing the patterns for these starters are similar in every respect to that shown in Fig. 161. Care, however, must be taken in placing the semi-profiles, as clearly shown in the diagram in Fig. 163, where the various starters are numbered to correspond to those shown in Fig. 162. It will be noticed that the inlets are round, while the outlets or stack connections are rectangular. This makes the methods of development as simple as that shown in Fig. 161. In this case it is only necessary to measure one altitude as *c d* in the diagrams in Fig. 163, whereas in Fig. 161 the altitudes varied, owing to the curve at 1 2 3. After the elevations of the starters have been drawn, the semi-profiles are placed as shown in Fig. 163. While the various hights must be taken in the semi-round profiles as in the previous development, it is only necessary to take the hight marked *c d* in all the diagrams, for the rectangular profiles. The elbow A is joined to starter number 5 to produce the starter shown by 5 in Fig. 162. After the patterns have been developed in Fig. 163, two inches should be added to the rectangular end of the patterns, to act as a collar, to receive the slip to which the pipe line is connected.

Offset Boot

Fig. 164 shows a perspective view of an offset boot round to "oval." In developing the patterns for this style of boot, the upper and lower pipes are developed by parallel lines, while the central piece is laid out by triangulation. The principles which

will be employed can be applied to this or any other style, regardless of what the profiles of the pipes may be.

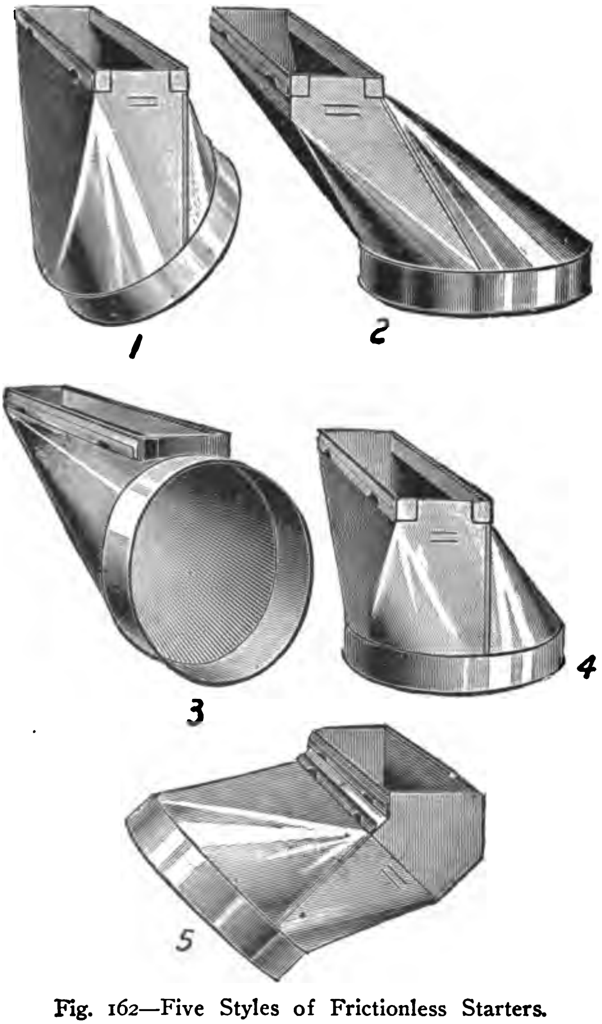

Fig. 162—Five Styles of Frictionless Starters.

Developing the Patterns

This is shown in detail in Fig. 165, in which the center line of the boot is first drawn as shown by *a* 3′ 8′ *e*, making the angles as desired. Bisect these angles to obtain a true miter

line as follows: From 3′ as center, with any desired radius, draw short arcs intersecting the center line at *a* and *b*; then using *a* and *b* as centers, with a radius slightly greater than before, draw the arcs intersecting at *c*, and draw the miter line indefinitely from *c* through 3′ as shown. In a similar manner obtain the miter line *f* 6′ by means of the arcs *d*, *e* and *f*. Now place the half profile of the round pipe at the lower end of the boot, on the line 1 5, and the half profile of the "oval" pipe on the upper end as shown on the line A B. Space the semi-circles in both profiles into the same number of parts, as indicated, and at right angles to 1 5 and A B respectively, draw lines from the various points 2 to 4 and 10 to 6 until they cut the miter lines 1′ 5′ and 6′ 10′ as shown. Connect by lines the points 1′ and 10′ and 5′ with 6′, which completes the side elevation. The half pattern for the round and "oval" pipes will be laid out by parallel lines as follows: Extend the line 1 5 in the side elevation as shown at the right by C D, upon which place the girth of the half profile of the round pipe as shown. From the small figures erect lines at right angles to C D, and intersect same by lines drawn parallel to C D from the various points 1′ to 5′ on the miter line in elevation. Trace a line through the intersection thus obtained; then will 1″ 5″ 5 1 be the half pattern to which the edges must be allowed for seaming.

In precisely the same manner is the half pattern for the oval pipe obtained. B A in elevation is extended as shown by *f* E, upon which the girth of the half profile of the "oval" pipe is placed, as shown by similar letters and figures on *f* E. The usual measuring lines are drawn and intersected by lines drawn parallel to *f* E from points of corresponding number on the miter line 6′ 10′. This will give the half pattern for the "oval" pipe, to which edges must also be allowed for seaming purposes.

To develop the middle piece of the offset, connect the various points 10′, 2′, 9′, 3′, etc., as shown. These lines will then represent the bases of sections to be constructed as shown in the diagram of true lengths, whose altitudes will equal the various hights shown by corresponding numbers in the upper and lower semi-profiles in the side elevation. Draw any horizontal line as F G, upon which place off the lengths of the several lines shown in the middle section in the elevation as shown by corresponding numbers on F G. For example, to find the true length of the line 3′ 9′ in elevation, take this distance and set it off on F G as shown from 3′ to 9′, and from these two points erect perpendiculars, making them equal respectively to the hight of lines of corresponding number in the half profiles of the side

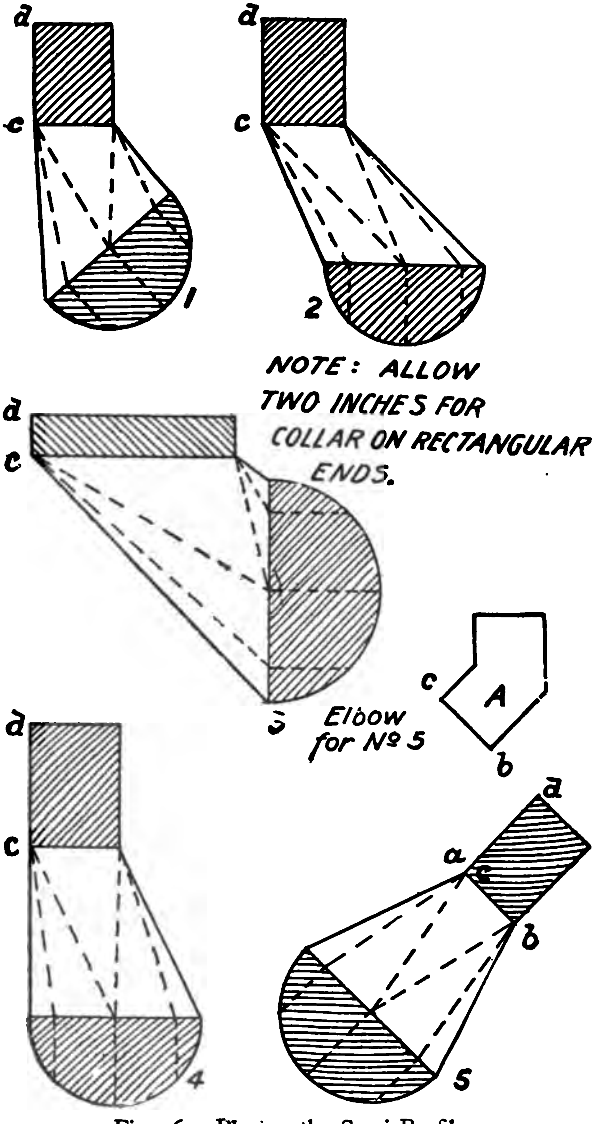

Fig. 163—Placing the Semi-Profiles.

elevation as measured from the lines 1 5 and A B, and draw a line from 3 to 9 in the diagram, which is the desired length. In this manner all of the true lengths are obtained. It should be understood that the lines 1′ 10′ and 5′ 6′ in elevation show their true lengths, but these two lines also represent the base of the two sections, whose altitudes at 10′ and 6′ are equal to A 10 and B 6 respectively, the true lengths of these two invisible lines being indicated by 1′ 10 and 5′ 6 in the diagram of true lengths.

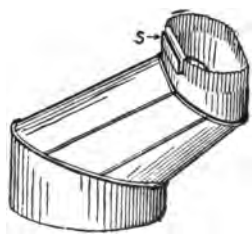

Fig. 164—Offset Boot.

It will not be necessary to develop any sections on the miter lines 1′ 5′ and 6′ 10′ in elevation as the true lengths along the miter cuts can be obtained along the miter cuts in patterns of the straight pieces respectively. The half pattern for the transition piece can now be laid out as follows: First draw any line as A 1 in the pattern equal to 10′ 1′ in the side elevation. With a radius equal to A 10 in the half profile and A in the pattern as center, describe the arc near 10, which intersect by an arc struck from 1 of the pattern as center and the true length 1′ 10 as radius. With 1″ 2″ in the half pattern of lower pipe as radius and 1 in the pattern as center, describe the arc 2, which intersect by an arc struck from 10 as center and 10 2 in diagram as radius. With 10′ 9′ in the half pattern of upper pipe as radius, and 10 in pattern as center, describe the arc near 9, which intersect by an arc struck from 2 of pattern as center and 2 9 in the diagram of true lengths as radius. Proceed in this manner, using alternately first the divisions along 1″ 5″ in the pattern for the lower pipe, with the proper true length in the diagram; then the divisions along A′ B′ in the pattern for the upper pipe, with the proper true length in the diagram, until all dimensions are used. A line traced through points thus obtained as shown by A B 5 1 completes the half pattern, to which edges must be allowed for seaming and joining. The method of seaming together the three pieces of the offset is similar to that shown in Fig. 127, but the wall pipe slips are made as indicated by S in Fig. 164.

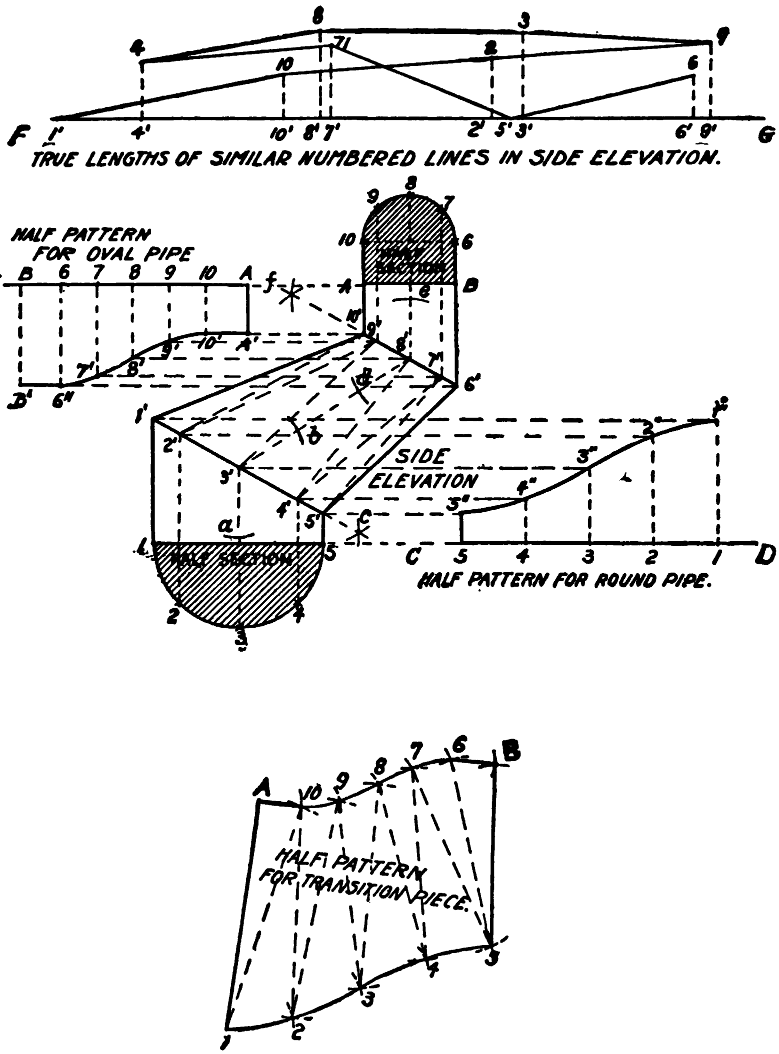

Fig. 165—Developing Pattern for Offset Boots.

Wall Pipes or Risers

The wall pipes used in warm air heating are also known as risers, stacks or flue pipes. They are made with single and double walls. When single wall pipes are used they should be braced on the inside by soldering a tin brace in the center of the pipe, as indicated by A in Fig. 166. Where this is not done

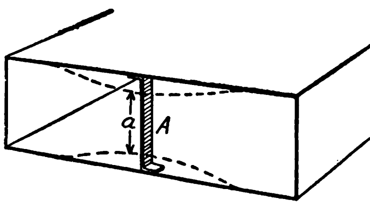

Fig. 166—How the Area Is Decreased in Wall Pipes.

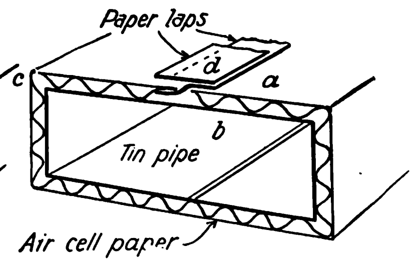

Fig. 167—Method of Securing Air Tight Joints in Wall Pipe.

the pressure of the plaster when forced through the lathing decreases the area of the pipe as indicated by the dotted lines *a* The braces A are cut ¾ inch wide and 1 inch longer than the width of the pipe. An ⅛ inch hem edge is turned on each of

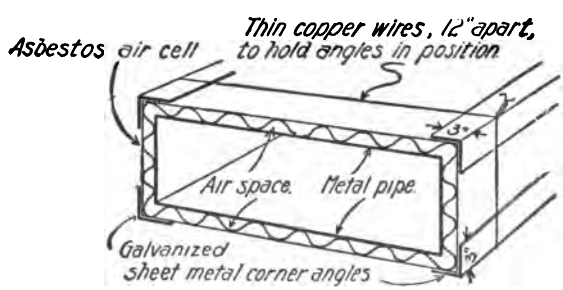

Fig. 168—Protecting Asbestos Covering.

the long sides of the brace, leaving it ½ inch, and a ½ inch edge on each end, which is turned at right angles to be used for soldering purposes as shown. Care must be taken to solder the brace in edgewise, so as not to interfere with the flow of the air or decrease the capacity of the pipe.

Covering Single Wall Pipes with Paper

The single wall pipes can be covered with either single paper or with air cell or corrugated paper. This prevents loss of heat in the walls, the paper being pasted to the flue pipes as follows:

Cut the paper about ¼ inch shorter than the girth required to go around the pipe. To apply the paper, roll it up, dip in water and remove immediately and apply the paste. Put the paper on the pipe while it is soft and pliable. Before bringing the two edges together in the vertical seam, take a piece of flat, stiff paper about 3 inches wide, and paste over one edge of the air cell paper as shown by *a* in Fig. 167, and then paste down on the tin pipe at *b*. Now bring the other edge of the air cell paper in place as shown by *c* and paste another strip of stiff paper over the joint as indicated by *d*. This secures the covering along the vertical joints. Do the same with the horizontal joints, and always have the corrugations next to the tin. When the paper is dry a good solid air tight covering is obtained.

Double Wall Pipes

Double wall pipes have the advantage over the single wall as the walls are protected from crushing by means of perforated angles and corrugations and the air space between the inner and outer pipes prevents loss of heat in the partitions.

Metal Flues in Brick Walls

When warm air pipes are run up in brick walls as the mason's work progresses, galvanized iron is generally used, covered with asbestos air cell covering. The corners of the asbestos covering is usually protected from injury as shown in Fig. 168, in which the metal pipe is first covered with asbestos air cell covering as previously described, then the corners of the asbestos covering are protected by galvanized sheet iron angles 3 inches wide on each side, which prevents the paper from being torn or damaged by the brick work or studding. These galvanized iron angles are held in position by thin copper wire twisted around the pipe at intervals of about 12 inches as indicated in the diagram.

The Various Fittings Used in Furnace Piping

Fig. 169 shows twenty-six styles of single wall furnace fittings, including every conceivable shape usually met with in practice. The same style of fittings can also be obtained for double wall pipe. It will be noticed that the various angles, elbows, offsets, tees, register boxes, etc., are so constructed that no development is necessary when laying out the patterns, the shapes being pricked direct on the metal and edges allowed for seaming and grooving. This cut should be referred to when any job comes up, as from these twenty-six styles one or more is sure to suggest itself for practical use.

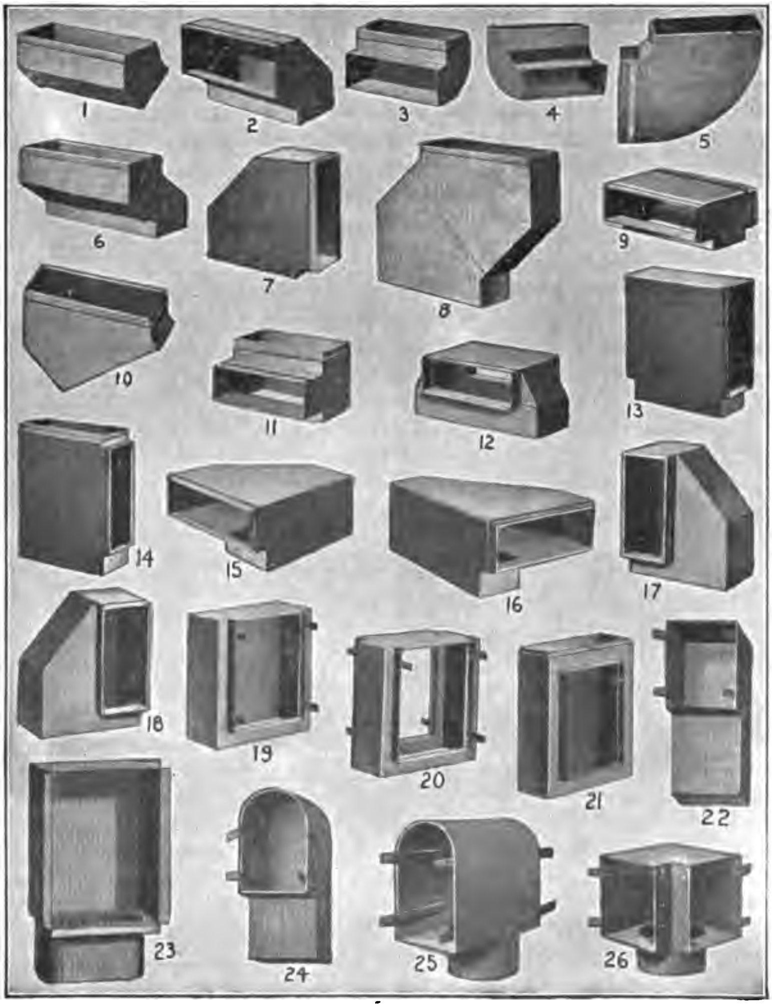

Fig. 169—Twenty-six Styles of Single Wall Furnace Fittings.

1—Angle 45° Elbow.
2—Elbow of Three Pieces.
3—Elbow 90°.
4—Regular Elbow 90° Round Heel.
5—Flat Elbow 90° Round Heel.
6—Offset Elbow.
7—Flat Elbow 90° Octagonal Heel.
8—Flat Offset Elbow.
9—Two Way Tee.
10—Flat Angle 45°.
11—Through Tee.
12—Reduced Tee.
13—Flat Two Way Tee.
14—Flat Through Tee.

15—Left Compound Tee on the Flat.
16—Right Compound Tee on the Flat.
17—Left Compound Tee on the Sharp.
Combined.
18—Right Compound Tee on the Sharp.
19—Single Top Register Box for Rectangular Riser.
20—Double Top Register Box for Rectangular Riser.
21—Through Register Box.
22—Top Register Box and Riser
23—Top Register Box Connected to Oval Pipe.
24—Semi-circular Register Box.
25—Double Semi-circular Register Boxes for Round Risers.
26—Double Corner Register Boxes for Round Riser.

Compound Wall Pipe Offsets

Compound pipe offsets are very often required in furnace piping. When the partition on the first floor runs in one direction, and that on the next floor runs at right angles to the lower one, a compound or double offset is necessary as shown in Fig 170, where the two wall pipes cross one another at right angles, with equal projection on all four sides as shown. In an offset of this kind the pattern must be developed, the offset usually being made up in four pieces, with collar attachment and the corners double seamed.

The method of developing the pattern for the offset is so clearly shown in Fig. 171 that little explanation will be required. The shape of the two pipes is clearly shown in the plan, the vertical hight of the offset is indicated by 2 *a* in elevation, and 1 2 of the elevation is the slant hight or stretchout to be used in obtaining the pattern as shown at the right. Allow for a collar at either end to make connections as shown.

Patterns for a Double Offset

When the upper heat pipe does not come centrally over the lower one, but offsets to one side, then a double offset is required as indicated in Fig. 172. The method of laying out the pattern is shown in Fig. 173, which method can be applied to any style of offset, regardless of what shape the profiles at either end may be, whether similar or dissimilar, or whether the upper pipe is out of center either way or not, providing, however, that the sides of the upper pipe run parallel to those of the lower pipe. Referring to Fig. 173, 2, 5, 3, 5 in plan shows the shape of the lower pipe and 1, 6, 4, 6 the shape of the upper pipe, the two being similar in this case. The amount of offset is equal to 3 1 in plan, the narrow side of the upper pipe being set centrally to the wide side of the lower one. The front and side elevations are projected from the plan as shown, being careful that the vertical hight *a* in the front is equal to *a'* of the side. As the flare 5 6 in the front elevation is the same as that of the opposite side, then will the pattern for one side answer for both.

In the side elevation the flares 1 2 and 3 4 are unequal; two patterns will therefore be required.

To obtain the pattern for the side shown by 5 6 in both front elevation and plan, proceed as follows: At right angles to the

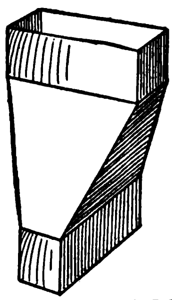

Fig. 170—Compound Offset.

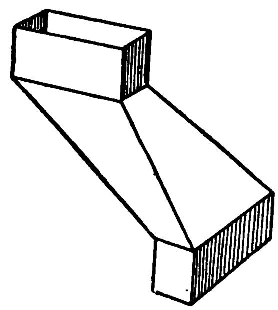

Fig. 172—Double Offset.

side 6 in plan draw the line A B, upon which place the girth or stretch-out of 5 6 in the front elevation as shown. At right angles to A B, through points 5 and 6, draw the usual measuring lines, and intersect same from sides of corresponding number in plan as shown, which will give the pattern for the sides 5 6. Allow for collars, also edges for seaming at the corners. For the

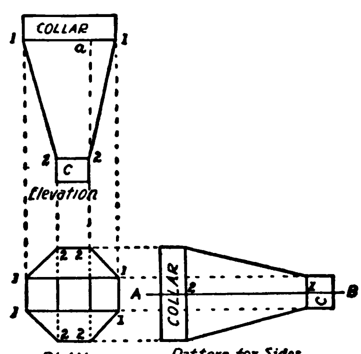

Fig. 171—Developing the Pattern for Compound Offset.

patterns for the sides 1 2 and 3 4 in the side elevation, draw any vertical line as C D below the plan as shown, upon which place the girth of the flares 1 2 and 3 4 in the side elevation. Through these small figures on C D draw the usual measuring lines, which intersect by lines projected from points of corresponding numbers in plan, all as shown by the dotted lines. Allow collars, also edges for seaming the corners.

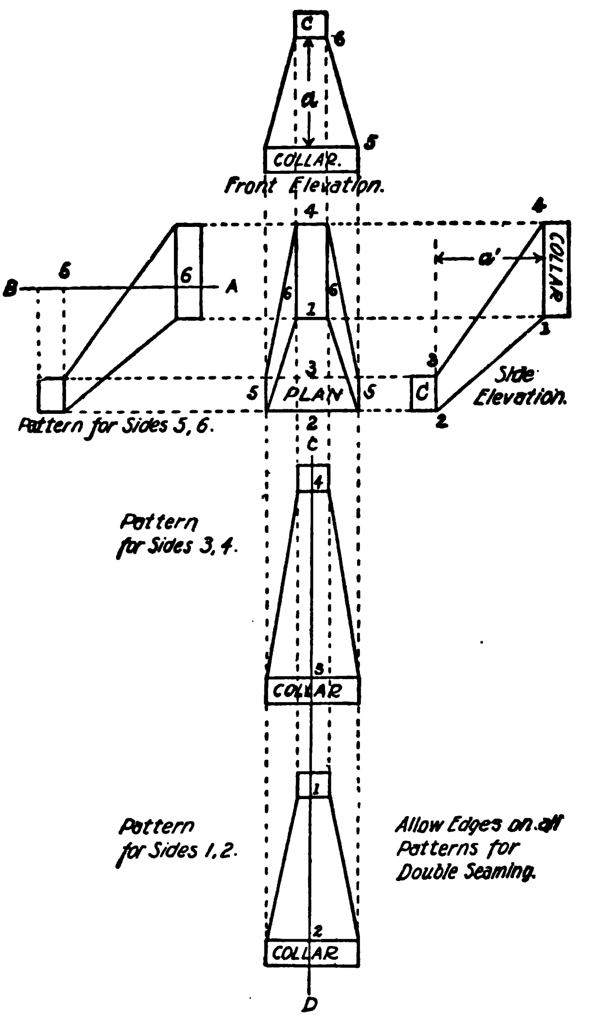

Fig. 173—Patterns for Double Offset.

Fittings for Trunk Line Heating Systems.

Where trunk line systems of heating are used, special fittings must be made up, which are usually round in section. Care, however, must be taken in designing the branches, tees and forks, that the main supply pipe is of sufficient area to feed the branches taken therefrom, as will be explained in problems to follow.

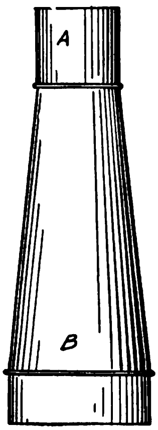

Fig. 174—Reducing Joint.

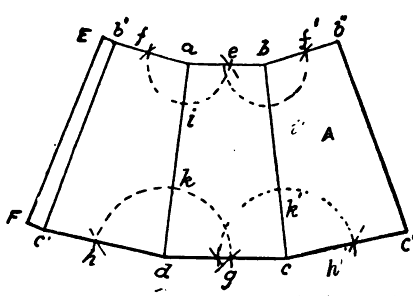

Fig. 175—Short Rule for Reducing Joint.

Five types of trunk line fittings will be shown. Four of the types will require triangulation in their development, but one type only will be developed in detail, showing the principles involved, which can be applied to the balance of the fittings or any other size or angles which may arise.

Short Rule for Reducing Joint

Fig. 174 shows what is known as a reducing joint. This pattern can be developed by the radial line system, but sometimes the difference between the large and small diameters is so little that the radius would become so long as to make it impractical for use. To overcome this a short rule can be used as shown in Fig. 175. This is as follows: Draw upon the sheet metal the outline of the taper joint desired, as shown by a b c d. Now with a and b as centers, with radius less than a b draw the arcs e f and e f', crossing the outlines a d and b c at i and i' respectively. Now using i as center with i e as radius intersect the arc at f. Do the same in obtaining f'. From a and b draw lines through f and f' equal in length to a b, as shown by a b' and b b''. In precisely the same manner, using d and c as centers, draw the arcs g h and g h' and obtain the intersections h and h'

by using *k* and *k'* as centers with radius equal to *k g*. From *d* and *c* draw lines through *h* and *h'*, making them equal in length to *d c*, as indicated by *d c'* and *c c''*. Draw lines from *b'* to *c'* and *b''* to *c''*. Add to the pattern just described one seventh of the shape *a b c d*, as shown by E F. This is obtained by dividing *a b* and *c d* each into seven parts and adding one of these parts as indicated. E. F. *b'' c''* is the desired pattern. When cutting out the pattern a curved line should be cut along the top and bottom, carefully allowing edges for grooving the joint and for seaming to the collars, as indicated by A and B in Fig. 174.

Determining the Unknown Diameter of the Main Pipe

Fig. 176 shows a view of an equal pronged fork fitting, in a trunk line system of heating. When laying out fittings of

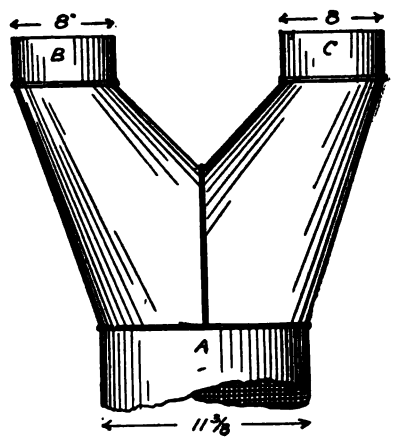

Fig. 176—Equal Fork in Trunk Line Fittings.

this kind, great care should be taken in regard to area, as before stated. In other words the area of the main trunk line A must equal the combined areas of the branches B and C, or as many branches as may be taken from the main.

To avoid computation when fitting the unknown diameter of the main pipe A, use can be made of a table of Circumferences and Areas of Circles to be found in chapter 19. Assuming that the two branches are each 8 inches in diameter, follow the column of diameters in the table to 8, the area of which will be found to be 50.26. Double this for the two similar branches, making a total of 100.52. Now following the column of areas in the table, the nearest area to 100.52 will be 101.62, which represents the area of a circle 11⅜ in. in diameter, as shown in the

column of diameters. The main pipe A must be 11⅜ in., which will then contain the combined areas of the two 8 in. branches B and C.

Pattern for a Fork of Equal Prongs in Trunk Line System

The pattern for this fitting will be developed by triangulation, as shown in detail in Fig. 177, the principles of which can also be applied to the other problems on fittings, which will follow

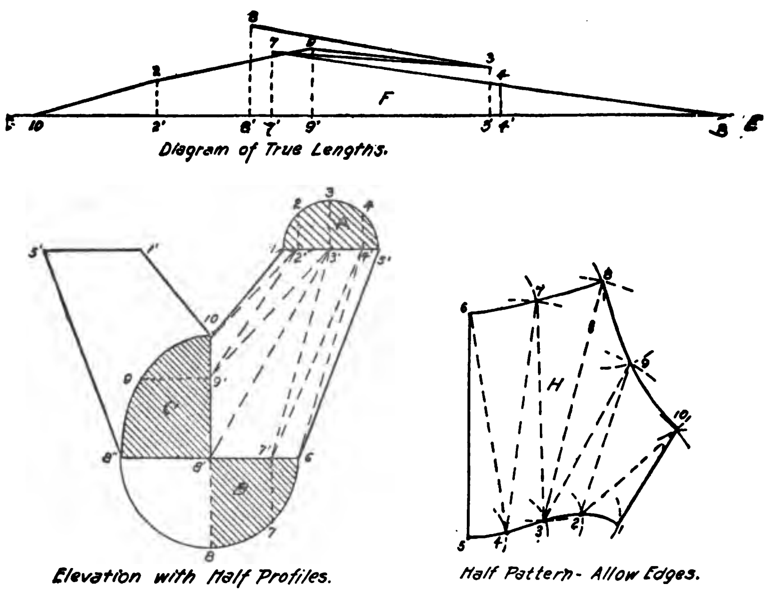

Fig. 177—Developing the Pattern for a Two-Pronged Fork.

in regular order. As both branches are to have the same diameter, the pattern for the one will answer for the other. First draw the elevation of the fork as shown by 1, 5, 6, 8″, 5′, 1′, 10 (in practice, but one half of elevation will be required, as both prongs are similar). On the line 1 5 in elevation draw the half-profile A; on the line 6 8″, the half-profile B, and draw the half-profile on the line 8′ 10 as follows: As the hight of the joint is equal to 8′ 10 and the half-depth through 8′ equal to 8′ 8, place this distance 8′ 8 at right angles to the joint line 8′ 10, as shown by 8′ 8″, and draw at pleasure a graceful quarter of an elliptical figure as indicated by 8″ 9 10 or C. As the half-profile B and C are both divided in two equal parts, or a total of four, then divide

the half-profile A into four spaces, as shown from 1 to 5; the half-profile B has two spaces, as shown from 6 to 8, and the half-profile C, in two parts, as shown from 8″ to 10. From these various small figures at right angles to their respective base lines, draw line intersecting the base lines at 2′, 3′, 4′, also at 7′ and 9′ Connect opposite points, as shown by the dotted lines. These lines then represent the base lines of sections which will be constructed and whose altitudes will be equal to the various heights in the half-profiles A, B and C. Therefore on any vertical line, as DE, place the various lengths of the lines in elevation, as shown. From the points on DE perpendiculars are erected whose hights are equal to the altitudes in the various half-sections, and the points, obtained in F, are then connected by slant lines, which show the true lengths, all as shown by similar numbers.

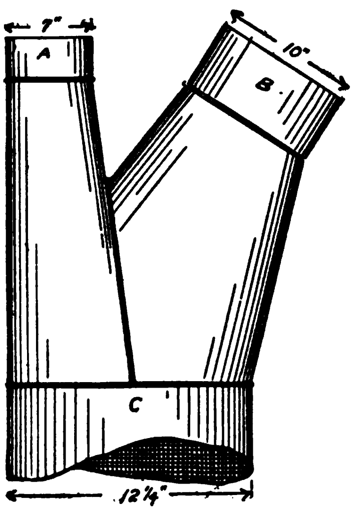

Fig. 178—Unequal Fork in Trunk Line Fittings.

The half pattern shape H briefly described is laid out as follows: 5 6 is made equal to 5 6 in elevation. The divisions from 5 to 1 are obtained from the half-section A, the divisions from 6 to 8 from the half-section B and the divisions from 8 to 10 from the half-section C. The length of the dotted lines in H are obtained from the true lengths in F, 1-10 in H being equal to 1-10 in elevation. Edges must be allowed for seaming.

Determining the Unknown Diameter in an Unequal Two Pronged Fork

Fig. 178 shows an unequal two pronged fork whose branches A and B are 7 and 10 inches respectively and it is desired to know what size the main pipe C must be. This is found without computation by using the table previously referred to. A 7 in. circle has an area of 38.48 sq. in., and a 10 in. circle an area of 78.54, making a total of 117.02. Now the nearest number to 117.02 in the column of areas in the table is 117.85, which suggests a circle 12¼ in. in diameter, or the size of the main pipe C.

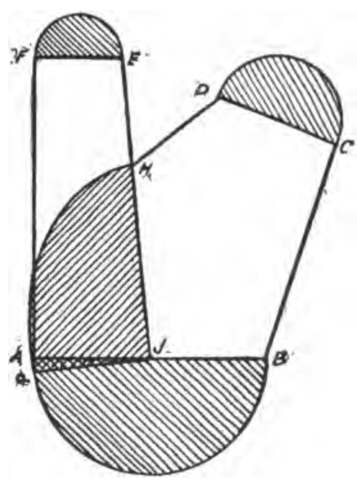

Fig. 179—Placing the Half-Profiles in an Unequal Pronged Fork.

Placing the Half Profiles Previous to Developing the Patterns

In Fig. 179 is shown how the half-profiles are to be placed when developing the patterns for an unequal pronged fork. Draw the outline of the full size fork as shown by A B C D H E F. Bisect A B and obtain the point J and draw the joint line J. H. Place semi-circles on the lines A B, C D and E F, which represent the half-profiles. At right angles to the joint line H J, from the center J, draw the line J *a* equal to J A, as shown, and draw a quarter elliptical figure shown by *a* H. The profiles being drawn, they are spaced and the patterns developed as was shown in Fig. 177.

Three Equal Pronged Fork

In Fig. 180 is shown a fork of three equal size prongs in a trunk line system, so placed that the pattern for one prong can

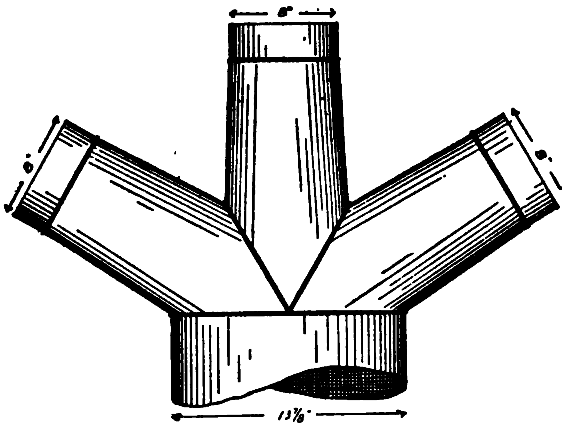

Fig. 180—Three Equal Pronged Fork in Trunk Line System.

be used for all three. The size of the main pipe would be determined as follows: Following the column of areas in the table, we find that 8 inch circle has an area of 50.26 sq. in., which

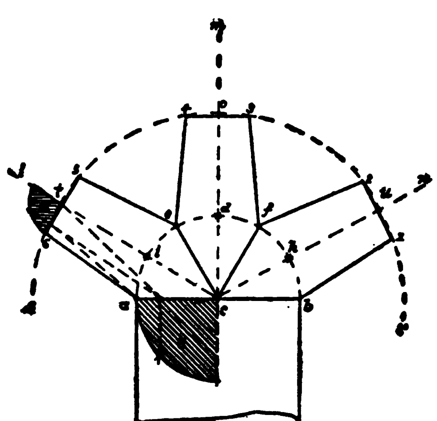

Fig. 181—Method of Drawing Three-Pronged Fork so that the Pattern for One Will Answer for All.

multiplied by 3 gives a total of 150.78. The nearest number to 150.78 in the column of areas is 151.20 and suggests a circle whose diameter is 13⅞ in., the size of the main pipe.

Method of Drawing Three Pronged Fork so that the Pattern for One Will Answer for All Three

Fig. 181 shows how a three pronged fork is drawn, so that the angles of the miter joints will be similar and the pattern for one will answer for all. Having determined the size of the main pipe as *a b*, bisect it, and obtain *c*, which use as a center

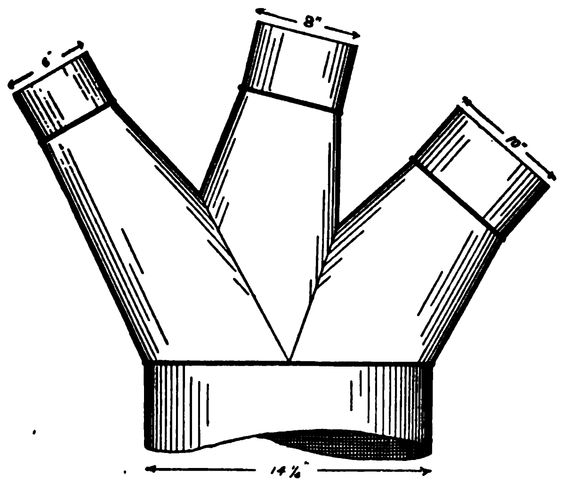

Fig. 182—Unequal Three-Pronged Fork in Trunk Line System.

and describe the semi-circle *a d b*. From *c* draw the perpendicular *c m*. Now set the dividers equal to *c a* and starting from *a*, step off the points *e* and *f*. Using the same space, step off the points *i* and *h*, starting from *d*. Draw the joint lines *c e* and *c f* and draw lines indefinitely from *c* through *i* and *h* shown respectively by *c l* and *c n*. Now establish the height of the prong as *c o* and, using *c* as center and *c o* as radius, draw the arc *r s*, cutting the radial lines *c l* and *c n* at *t* and *u*. On ascertaining the diameter of the prong, set the dividers equal to one-half the diameter and step off on the arc *r s* on either side of the points *u o* and *t*, the divisions shown by 1 2, 3 4 and 5 6. Connect these points by lines as indicated, which makes each of the three prongs similar. As the two halves of each prong are symmetrical, it is only necessary to develop the pattern for one half, as indicated by *a* 6 *t c*, placing the quadrants for that purpose as follows: With *c* as center and *c a* as radius, draw the quadrant shown shaded, at B. With *t* as center and *t* 6 as radius, draw the quadrant shown by A. Now divide both quadrants in equal number of spaces and proceed to draw the base lines and develop the true lengths and patterns as previously described.

Unequal Three Pronged Fork

Fig. 182 shows an unequal three pronged fork, each diameter being different, and each fork leading at a different angle. In this case the diameters are 6, 8 and 10 in. and represent areas of 28.27, 50.26 and 78.54, making a total area of 157.07. The nearest area to this number is 159.48 and represents the area of a 14¼ in. pipe, the desired dimensions as shown.

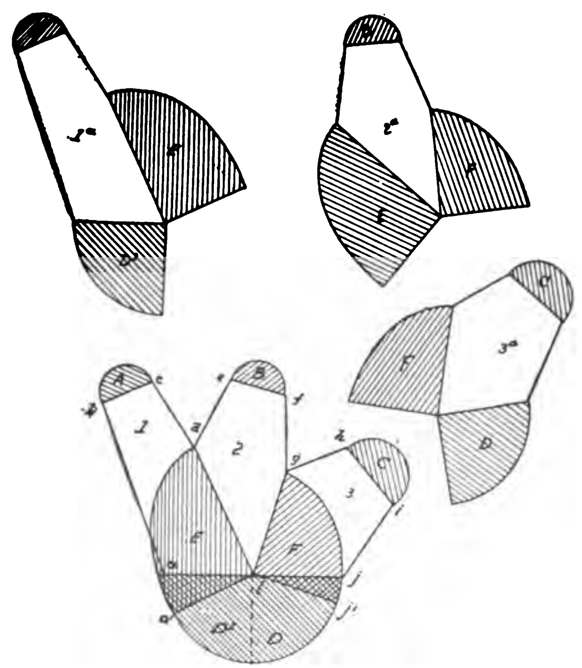

Fig. 183—Finding True Sections and Placing Profiles.

Finding the True Sections and Placing the Profiles in an Unequal Three Pronged Fork

While the method of developing the patterns for an unequal three pronged fork is similar to those already described, care must be taken to draw and place the profiles properly, as is shown in Fig. 183. In this figure *a b c d e f g h i j* shows the desired outline of the fork and that it has the desired angles and proper dimensions and diameters. On the line *a j* draw the semicircle D, and on the lines *b c, e f* and *h i* the half-profiles A, B

and C respectively. Now at right angles to the joint lines *d l* and *l g* draw the lines *l a'* and *l j'* equal respectively to *l a* and *l j*. Now from the intersections *a'* and *j'* draw the quarter elliptical figures indicated by *a' d* and *j' g*, or E and F. So that the method of placing the half-profiles may not confuse the reader, the prongs have been numbered 1, 2 and 3 and have been duplicated as indicated by 1^a, 2^a and 3^a, on which the profiles are placed in their proper positions, being duplicates of similar lettered profiles in 1, 2 and 3. A little study will make this clear, after which the spacing of the profiles and obtaining the true lengths and the patterns are in order.

Finding True Angles in Cold Air Duct Elbows

It is often the case that special elbows must be prepared and the true angle be found, especially where they pitch in both directions, as indicated in Fig. 184, where a plan and elevation of a

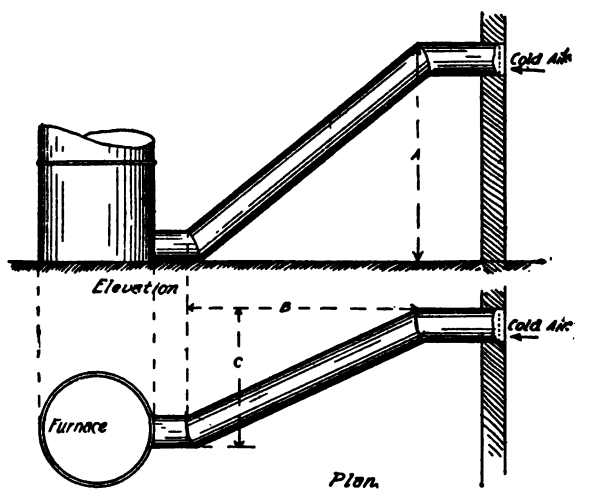

Fig. 184—Example in Cold Air Duct Elbows in Furnace Work.

round cold air duct is shown. In this case true angles must be found, as none of the angles in either plan or elevation show their true pitch. The height of the elbow from the cellar line is indicated by A, its projection by B in plan, and it leans away from the reader as much as is indicated by C. The method of finding the true length of the middle pipe, also the true angles of the two elbows, is indicated in the detail drawing in Fig. 185, in which the heavy dotted lines show the center line of the pipe, all that is necessary. A B C D represents the center of

the pipe in plan, its lean away from the reader being shown by a D. The same center line is shown in elevation by A^1 B^1 C^1 D^1, the rise being indicated by b C^1 and the projection by B^1 b. The first step in finding the true length of B C in plan or B^1 C^1 in elevation is to place the height of b C^1 at right angles to B C in plan, as indicated by C C^2, and draw a line from C^2 to B, the desired length. As A B and C D in plan and A^1 B^1 and C^1 D^1 in elevation lie in horizontal planes, they then show their true lengths. Now to find the true angle of A B C in plan, draw a line from A to C, take this distance and place it on any line as A C in diagram X and at right angles to A C draw C C^1 equal to b C^1 in elevation. Draw a line from C^1 to A, which is the true length of C A in plan. Now with the true length C^2 B in plan as radius and C^1 in diagram X as center, draw the arc E, which intersect by an arc struck from A as center and A B in plan or A^1 B^1 in elevation as radius. The dotted line drawn from C^1 to E to A shows the true angle for the elbows for A^1 B^1 C^1 in elevation or A B C in plan.

The true angle on B C D in plan is obtained in a similar manner. The distance from B to D in plan is placed as shown by B D in diagram Y, perpendicular to which D C^1 is erected equal to b C^1 in elevation. Then with C D and B C^2 in plan as radii, and using C^1 and B respectively in diagram Y as centers, arcs are intersected at H, thus forming the desired true angle B H C^1.

Method Employed when Developing the Elbow Patterns

After the true angles have been found the patterns are laid out similarly to other elbow work. For example, the angle A E C^1 is bisected, thus obtaining the line c d and the profile F of the pipe placed as shown, with the center point a placed upon the line E C^1. The profile is now divided into equal spaces and the pattern obtained as usual. Of course it is understood that the arms of the elbows are usually made about 6 in. long at the throat, making a slip joint for the center pipe, no matter how short this may be. This method obviates the labor of finding the amount of twist between the two elbows B^1 and C^1 in elevation.

True Angles in Warm Air Elbows

When true angles are required in warm air elbows the same principles are employed. Fig. 186 gives an example of what is likely to arise in practice. This shows a pipe line connecting to the first floor register. In elevation the rise is equal to a and b respectively, while in plan the pipe leans toward the reader

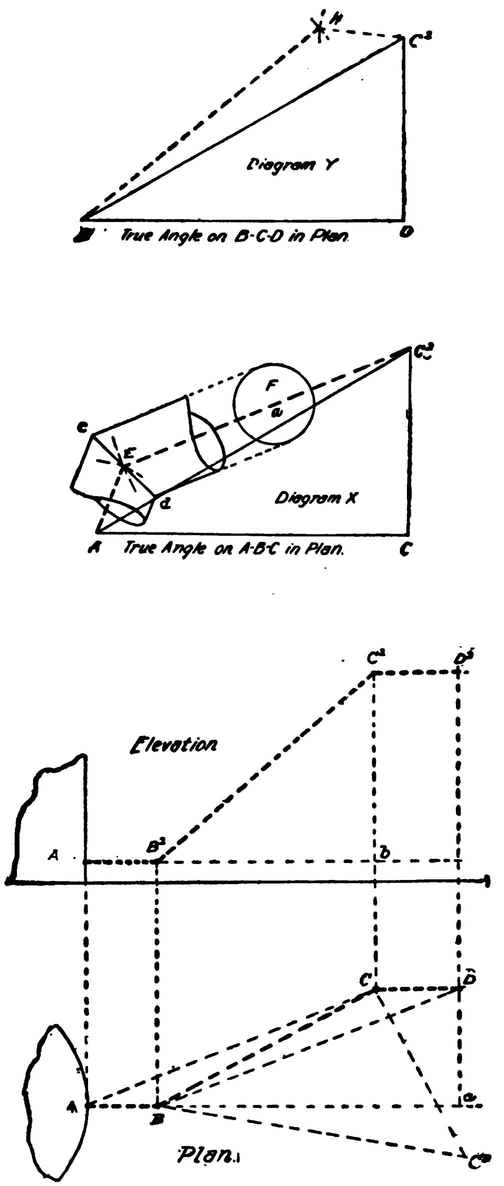

Fig. 185—Finding True Angles of Circular Cold Air Duct.

as much as indicated by *c*. This problem has been worked out in Fig. 187, in which A B C D shows the rise of the center line

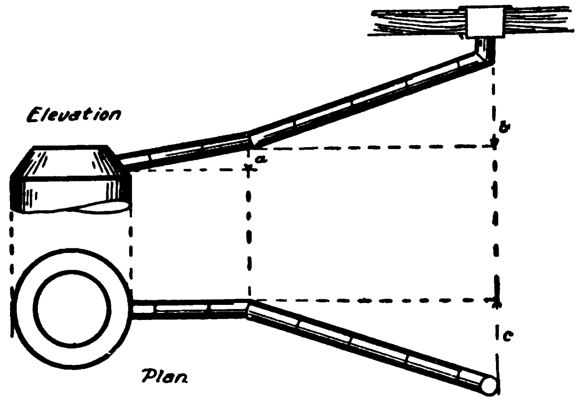

Fig. 186—Example in Finding True Angles in Warm Air Elbows.

of the pipe in elevation. The first run of pipe A B has a rise equal to *a* B, while the second run B C has a rise equal to *b* C,

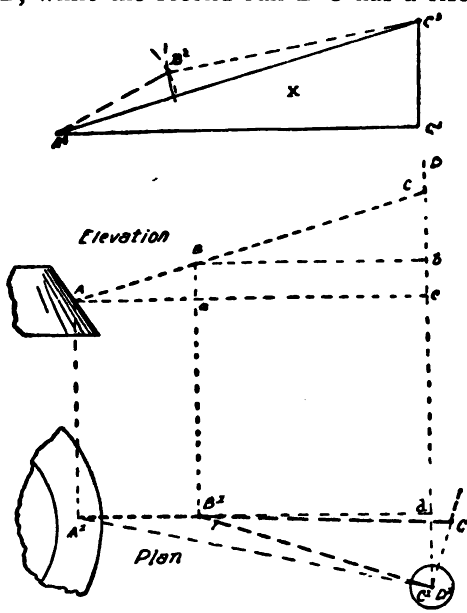

Fig. 187—Finding the True Angles.

the pipe C D being made to suit the connection to the register box.

A^1 B^1 C^1 in plan shows similar center line of pipe, leaning toward the reader a distance equal to d C^1. The center line of the pipe C D in elevation is indicated in plan by the dot C^1 D^1. Now to find the true length of the run B C and the true angle of B C D in elevation, proceed as follows: Take the hight from *b* to C to D in elevation and place it at right angles to B^1 C^1 in plan as shown respectively by C^1 to C^2 to D^2 and draw the lines

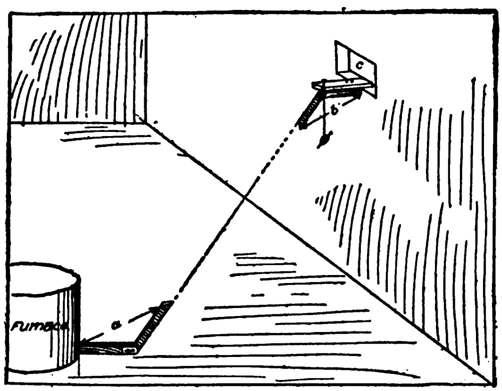

Fig. 188—Finding True Angles with Line and Bevel.

from B^1 to C^2 to D^2, which will give the true length as well as the true angle of B C and B C D in elevation. As A^1 B^1 in plan lies in a horizontal plane, then A B in elevation shows its true length. To obtain the true angle of A B C in elevation or A^1 B^1 C^1 in plan, take the distance of A^1 C^1 and place it in X as shown. From C^1 erect the perpendicular C^1 C^3 equal to the combined hights of the two runs in elevation, as *c* *b* C. Now with radii equal to A B in elevation and B^1 C^2 in plan and using A^1 and C^3 in X as centers, intersect arcs at B^2. A^1 B^2 C^3 then becomes the true angle desired. The patterns are developed in exactly the same way as before described.

Finding True Angles with Line and Bevel

A practical way to find the true angles without any drawing is to do it directly at the job, using only a line and bevel, and is shown in connection with Fig. 188. The furnace and cold air inlet *c* being in position, nail a slat on the inlet sill, as far as the pipe is to project from the wall, as shown; also put a nail in the concrete floor near the furnace where desired. Now drive a

nail at the end of the slat and draw a line taut from *b* to *a*. It is now an easy matter to place a bevel at *a* and *b*, then take dimensions at the inside corners of the bevel legs, after which the bevel can be closed, and then again opened when the patterns are laid out in the shop. Before removing the line, the true length from *a* to *b* can be measured.

CHAPTER XIX

RULES, TABLES AND INFORMATION

The following pages contain rules, tables and useful information of value to the sheet metal worker and furnace man.

This information has been collected from so many sources that it is next to impossible to give credit to the authors or compilers of the data and tables published.

The author of this book desires to acknowledge his obligation to each of those who are in any way responsible for the data published, believing that no objection will be made to the use of the information for the benefit of the trade.

Weights of Steel

No. of Gauge	Approximate thickness in fractions of an inch U. S. Standard	Approximate Thickness in decimal parts of an inch U. S. Standard	Weight per square foot in pounds Avoirdupois Iron	Weight per square foot in pounds Avoirdupois Steel	Birmingham	No of Gauge
0000000	1-2	.5	20.00	20.4	....	7°
000000	15-32	.46875	18.75	19.125	....	6°
00000	7-16	.4375	17.50	17.85	....	5°
0000	13-32	.40625	16.25	16.575	.454	4°
000	3-8	.375	15.	15.30	.425	3°
00	11-32	.34375	13.75	14.025	.380	2°
0	5-16	.3125	12.50	12.75	.340	0
1	9-32	.28125	11.25	11.475	.300	1
2	17-64	.265625	10.625	10 8375	.284	2
3	1-4	.25	10.	10.2	.259	3
4	15-64	.234375	9.375	9.5625	.238	4
5	7-32	.21875	8.75	8.925	.220	5
6	18-64	.203125	8.125	8.2875	.203	6
7	3-16	.1875	7.5	7.65	.180	7
8	11-64	.171875	6.875	7.0125	.165	8
9	5-32	.15625	6.25	6.375	.148	9
10	9-64	.140625	5.625	5.7375	.134	10
11	1-8	.125	5.	5.1	.120	11
12	7-64	.109375	4.375	4.4625	.109	12
13	3-32	.09375	3.75	3.825	.095	13
14	5-64	.078125	3.125	3.1875	.083	14
15	9-128	.0703125	2.8125	2.86875	.072	15
16	1-16	.0625	2.5	2.55	.065	16
17	9-160	.05625	2.25	2.295	.058	17
18	1-20	.05	2.	2.04	.049	18
19	7-160	.04375	1.75	1.785	.042	19
20	3-80	.0375	1.50	1.53	.035	20
21	11-320	.034375	1.375	1.4025	.032	21
22	1-32	.03125	1.25	1.275	.028	22
23	9-320	.028125	1.125	1.1475	.025	23
24	1-40	.025	1.	1.02	.022	24
25	7-320	.021875	.875	.8925	.020	25
26	3-160	.01875	.75	.765	.018	26
27	11-640	.0171875	.6875	.70125	.016	27
28	1-64	.015625	.625	.6375	.014	28
29	9-640	.0140625	.5625	.57375	.013	29
30	1-80	.0125	.5	.51	.012	30
31	7-640	.0109375	.4375	.44625	.010	31
32	13-1280	.01015625	.40625	.414375	.009	32
33	3-320	.009375	.375	.3825	.008	33
34	11-1280	.00859375	.34375	.350625	.007	34
35	5-640	.0078125	.3125	.31875	.005	35
36	9-1280	.00703125	.28125	.286875	.004	36
37	17-2560	.006640625	.265625	.2709375	....	37
38	1-160	.00625	.25	.255	....	38
..	.....	....	....	....	....	39
..	....	....	....	....	....	40

GAUGES AND WEIGHTS OF BLACK SHEETS.

No. of Gauge or Thickness of Sheet	Approximate Thickness in Inches.				Weight per Square Foot in Pounds		
	U. S. Standard, adopted by U. S. Government July 1, 1893		Birmingham Wire Gauge	American or Brown & Sharpe's	U. S. Standard	Birmingham Wire Gauge	American or Brown & Sharpe's
	Fractions	Decimals	Decimals	Decimals	Steel	Steel	Steel
5-0's	7-16	.437	.....	.....	17.50	.....	.....
0000	13-32	.406	.454	.46	16.25	18.46	18.77
000	3-8	.375	.425	.409	15.	17.28	16.71
00	11-32	.343	.38	.364	13.75	15.45	14.88
0	5-16	.312	.34	.324	12.50	13.82	13.26
1	9-32	.281	.30	.289	11.25	12.20	11.80
2	17-64	.265	.284	.257	10.625	11.55	10.51
3	1-4	.25	.259	.229	10.	10.53	9.36
4	15-64	.234	.238	.204	9.375	9.68	8.34
5	7-32	.218	.22	.181	8.75	8.95	7.42
6	13-64	.203	.203	.162	8.125	8.25	6.61
7	3-16	.187	.18	.144	7.5	7.32	5.89
8	11-64	.171	.165	.128	6.875	6.71	5.24
9	5-32	.156	.148	.114	6.25	6.02	4.67
10	9-64	.140	.134	.101	5.625	5.45	4.16
11	1-8	.125	.12	.09	5.	4.88	3.70
12	7-64	.109	.109	.08	4.375	4.43	3.30
13	3-32	.093	.095	.072	3.75	3.86	2.94
14	5-64	.078	.083	.064	3.125	3.37	2.62
15	9-128	.070	.072	.057	2.8125	2.93	2.33
16	1-16	.062	.065	.05	2.5	2.64	2.07
17	9-160	.056	.058	.045	2.25	2.36	1.85
18	1-20	.05	.049	.04	2.	1.99	1.64
19	7-160	.043	.042	.035	1.75	1.71	1.46
20	3-80	.037	.035	.032	1.50	1.42	1.31
21	11-320	.034	.032	.028	1.375	1.30	1.16
22	1-32	.031	.028	.025	1.25	1.14	1.03
23	9-320	.028	.025	.022	1.125	1.02	.922
24	1-40	.025	.022	.020	1.	.895	.82
25	7-320	.021	.02	.017	.875	.813	.73
26	3-160	.018	.018	.015	.75	.732	.649
27	11-640	.017	.016	.014	.6875	.651	.579
28	1-64	.015	.014	.012	.625	.569	.514
29	9-640	.014	.013	.011	.5625	.....	.461
30	1-80	.012	.012	.01	.5	.....	.408
31	7-640	.010	.01	.008	.4375	.....	.363
32	13-1280	.010	.009	.008	.4062	.....	.326
34	11-1280	.008	.007	.006	.3437	.....	.257
36	9-1280	.007	.004	.....	.2812	.....	.....

The U. S. Standard Gauge is the one commonly used in the United States.

In figuring weights of Steel Plates add to above the allowances for overweight, adopted by Association American Steel Manufacturers.

GALVANIZED SHEETS.

GAUGES, WEIGHTS AND NUMBER SHEETS IN BUNDLE

Size of Sheet	Weight of Sheet	Weight of Bundle	Number of Sheets	Size of Sheet	Weight of Sheet	Weight of Bundle	Number of Sheets	Size of Sheet	Weight of Sheet	Weight of Bundle	Number of Sheets
No. 14 (3.28 lbs. sq. ft.)				**No. 16** (2.65 lbs. sq. ft.)				**No. 18** (2.15 lbs. sq. ft.)			
24x72	39.37	157	4	24x72	31.87	159	5	24x72	25.87	155	6
26x72	42.65	170	4	26x72	34.5	138	4	26x72	28.	140	5
28x72	45.9	138	3	28x72	37.18	148	4	28x72	30.18	150	5
30x72	49.2	147	3	30x72	39.84	159	4	30x72	32.34	161	5
36x72	59.	177	3	36x72	47.8	143	3	36x72	38.8	155	4
24x84	45 9	137	3	24x84	37.18	149	4	24x84	30.18	151	5
26x84	49.74	149	3	26x84	40.2	161	4	26x84	32.68	163	5
28x84	53.58	161	3	28x84	43.37	173	4	28x84	35.2	140	4
30x84	57.4	172	3	30x84	46.48	139	3	30x84	37.7	151	4
36x84	68.9	137	2	36x84	55.78	167	3	36x84	45.28	135	3
24x96	52.5	157	3	24x96	42.5	170	4	24x96	34.5	138	4
26x96	56.8	170	3	26x96	46.	138	3	26x96	37.36	149	4
28x96	61.2	183	3	28x96	49.56	149	3	28x96	40.23	161	4
30x96	65.6	131	2	30x96	53.12	159	3	30x96	43.12	172	4
36x96	78.75	157	2	36x96	63.75	127	2	36x96	51.75	155	3
No. 20 (1.65 lbs. sq. ft.)				**No. 22** (1.40 lbs. sq. ft.)				**No. 24** (1.15 lbs. sq. ft.)			
24x72	19.87	159	8	24x72	16.87	151	9	24x72	13.87	152	11
26x72	21.53	151	7	26x72	18.28	146	8	26x72	15.03	150	10
28x72	23.18	162	7	28x72	19.68	157	8	28x72	16.18	145	9
30x72	24.84	149	6	30x72	21.	147	7	30x72	17.34	156	9
36x72	29.8	149	5	36x72	25.3	152	6	36x72	20.8	145	7
24x84	23.18	162	7	24x84	19.68	157	8	24x84	16.18	145	9
26x84	25.1	150	6	26x84	21.3	149	7	26x84	17.52	140	8
28x84	27.	135	5	28x84	22.96	160	7	28x84	18.88	151	8
30x84	28.97	145	5	30x84	24.6	148	6	30x84	20.23	141	7
36x84	34.78	139	4	36x84	29.53	147	5	36x84	24.28	145	6
24x96	26.5	159	6	24x96	22.5	157	7	24x96	18.5	148	8
26x96	28.7	143	5	26x96	24.37	146	6	26x96	20.	160	8
28x96	30.9	154	5	28x96	26.24	157	6	28x96	21.57	151	7
30x96	33.12	166	5	30x96	28.12	140	5	30x96	23.12	162	7
36x96	39.75	159	4	36x96	33.75	169	5	36x96	27.75	166	6
No. 26 (.906 lbs. sq. ft.)				**No. 27** (.843 lbs sq. ft.)				**No. 28** (.781 lbs. sq. ft.)			
24x72	10.87	152	14	24x72	10.12	151	15	24x72	9.37	149	16
26x72	11.78	153	13	26x72	10.96	153	14	26x72	10.15	152	15
28x72	12.68	152	12	28x72	11.81	153	13	28x72	10.93	153	14
30x72	13.57	149	11	30x72	12.65	151	12	30x72	11.71	152	13
36x72	16.3	146	9	36x72	15.18	151	10	36x72	14.06	155	11
24x84	12.68	152	12	24x84	11.81	153	13	24x84	10.93	153	14
26x84	13.73	151	11	26x84	12.78	153	12	26x84	11.84	153	13
28x84	14.79	148	10	28x84	13.77	151	11	28x84	12.75	153	12
30x84	15.85	152	10	30x84	14.76	147	10	30x84	13.67	150	11
36x84	19.03	154	8	36x84	17.7	159	9	36x84	16.4	148	9
24x96	14.5	145	10	24x96	13.5	148	11	24x96	12.5	150	12
26x96	15.7	157	10	26x96	14.62	146	10	26x96	13.53	148	11
28x96	16.9	152	9	28x96	15.74	157	10	28x96	14.57	146	10
30x96	18.12	145	8	30x96	16.87	152	9	30x96	15.62	156	10
36x96	21.75	152	7	36x96	20.25	162	8	36x96	18.75	150	8

SHEET COPPER

TABLE OF WEIGHT PER SQUARE FOOT, AND THICKNESS, PER STUBS' WIRE GAUGE.

Stubs' Guage (nearest No.)	Thickness in decimal parts of 1 inch	Ounce per square foot	14x48 lbs.	24x96 lbs.	30x60 lbs.	24x72 lbs.	30x96 lbs.	36x96 lbs.	30x120 lbs.
35	.00537	4	1.16	4	3.12	3.	5.	6.	6.24
33	.00806	6	1.75	6	4.68	4.50	7 50	9.	9.36
31	.0107	8	2.33	8	6.25	6.	10.	12.	12.50
29	.0134	10	2.91	10	7.81	7.50	12.50	15.	15.62
27	.0161	12	3.50	12	9.37	9.	15.	18.	18.74
26	.0188	14	4.08	14	10.93	10.50	17.50	21.	21.86
24	.0215	16	4.66	16	12.50	12.	20.	24.	25.
23	.0242	18	5.25	18	14.06	13.50	22.50	27.	28.12
22	.0269	20	5.83	20	15.62	15.	25.	30.	31.24
21	.0322	24	7.	24	18.75	18.	30.	36.	37.50
19	.0430	32	9.33	32	25.	12.	40.	48.	50.
18	.0538	40	11.66	40	31.25	30.	50.	60.	62.50
16	.0645	48	14.	48	37.50	36.	60.	72.	75.
15	.0754	56	16.33	56	43.75	42.	70.	84.	87.50
14	.0860	64	18.66	64	50.	48.	80.	96.	100.
13	.095	70	...	70	55.	52.50	87.50	105.	110.
12	.109	81	...	81	63.	61.	101.25	121.50	126.
11	.120	89	...	89	70.	67.	111.50	133.50	140.
10	.134	100	...	100	78.	75.	125.	150.	156.
9	.148	110	...	110	86.	82.50	137.50	165.	172.
8	.165	123	...	123	96.	92.	153.75	184.50	192.
7	.180	134	...	134	105.	100.50	167.50	201.	210.
6	.203	151	...	151	118.	113.50	188.75	226.50	236.
5	.220	164	...	164	128.	123.	205.	246.	256.
4	.238	177	...	177	138.	133.	221.25	265.50	276.
3	.259	193	...	193	151.	144.	241.25	289.50	302.
2	.284	211	...	211	165.	158.	263.75	316.50	330.
1	.300	223	...	223	174.	168.	278.75	334.50	348.
0	.340	253	...	253	198.	190.	316.25	379.50	396.

These weights are theoretically correct, but variations must be expected in practice.

APPROXIMATE WEIGHT OF SHEET ZINC.

Zinc Numbers	Weight per Square Foot.	Thickness in decimals of an Inch.	American or U. S. Gauge.	Average weight per sheet 36x84 Pounds.
5	.37	.010 ($\frac{1}{100}$)	32	7.77
6	.45	.012	30	9.45
7	.52	.014	29	10.92
8	.60	.016	28	12.90
9	.67	.018	26	14.32
10	.75	.020 ($\frac{1}{50}$)	25	17.16
11	.90	.024	24	20.00
12	1.05	.028	23	22.84
13	1.20	.032	22	25.20
14	1.35	.036	21	28.52
15	1.50	.040 ($\frac{1}{25}$)	20	31.50
16	1.68	.045	19	35.28
17	1.87	.050	18	39.27
18	2.06	.055	17	45.55
19	2.25	.060 ($\frac{1}{17}$)	16	47.25
20	2.62	.070	15	55.02
21	3.00	.080	14	63.00
22	3.37	.090	13	70.77
23	3.75	.100 ($\frac{1}{10}$)	12	78.75
24	4.70	.125 ($\frac{1}{8}$)	11	98.70
25	9.40	.250 ($\frac{1}{4}$)	3	197.40
26	14.10	.375 ($\frac{3}{8}$)	000	296.10
27	18.80	.500	0000000	......
28	37.60	1.000		......

WEIGHTS OF GALVANIZED PIPE AND ELBOWS

SMOKE PIPE—JOINTS 26" LONG.

24 GAUGE

7" Diam. Lock Seam	4 lb. 8 oz.
8" Diam. Lock Seam	5 lb. 2 oz.
9" Diam. Lock Seam	6 lb. 2 oz.

26 GAUGE

7" Diam. Lock Seam	3 lb. 9 oz.
8" Diam. Lock Seam	4 lb. 3 oz.

ELBOWS—4 PIECE.

24 GAUGE

7" Diam.	1 lb. 11 oz.
8" Diam	2 lb. 9 oz
9" Diam.	3 lb. 8 oz.

26 GAUGE

7" Diam.	1 lb. 8 oz.
8" Diam.	1 lb. 14 oz
9" Diam.	2 lb. 6 oz.

NET WEIGHT PER BOX TIN PLATES.

Basis, 10 x 14, 225 Sheets; or, 14 x 20, 112 Sheets.

Trade Term		80 lb	85 lb	90 lb	95 lb	100 lb	IC	IXL	IX	IXX	IXXX	IXXXX
Approximate Wire Gauge		No. 33	No. 32	No. 31	No. 31	No. 30	No. 30	No. 28	No. 28	No. 27	No. 26	No. 25
Wt. pr. Box, lbs.		80	85	90	95	100	107	128	135	155	175	195
Size of Sheets	Sheets per box.											
10 x14	225	80	85	90	95	100	107	128	135	155	175	195
14 x20	112	80	85	90	95	100	107	128	135	155	175	195
20 x28	112	160	170	180	190	200	214	256	270	310	350	390
10 x20	225	114	121	129	136	143	153	183	193	221	250	279
11 x22	225	138	147	156	164	172	184	222	234	268	302	337
11½x23	225	151	161	170	179	189	202	242	255	293	331	368
12 x24	112	82	87	93	98	103	110	132	139	159	180	201
13 x13	225	97	103	109	115	121	129	154	163	187	211	235
13 x26	112	97	103	109	115	121	129	154	163	187	211	235
14 x28	112	112	119	126	133	140	150	179	189	217	245	273
15 x15	225	129	137	145	153	161	172	206	217	249	281	313
16 x16	225	146	155	165	174	183	196	234	247	283	320	357
17 x17	225	165	175	186	196	206	221	264	279	320	361	403
18 x18	112	93	98	104	110	116	124	148	156	179	202	226
19 x19	112	103	110	116	122	129	138	165	174	200	226	251
20 x20	112	114	121	129	136	143	153	183	193	221	250	279
21 x21	112	126	134	142	150	158	169	202	213	244	276	307
22 x22	112	138	147	156	164	172	184	221	234	268	202	337
23 x23	112	151	161	170	179	189	202	242	255	295	333	370
24 x24	112	164	175	185	195	204	220	263	278	320	360	401
26 x26	112	193	205	217	229	241	258	309	326	374	422	471
13½x19½	112	75	80	85	89	94	100	...	...	...	...	...
14 x21	112	84	89	95	100	105	112	...	...	...	...	...
14 x22	112	88	94	99	105	110	118	...	...	...	...	...
16 x20	112	91	97	103	109	114	122	...	...	...	...	...
14 x31	112	124	132	140	147	155	166	...	...	...	...	...
15½x23	112	102	108	115	121	127	136	...	...	...	...	...

COST OF TIN FOR STANDING SEAM ROOFING.

Size, 20 x 28 inches.

Price per box, per square foot and per hundred square feet.

When Tin Costs.	S. S. Roofing Costs.	S. S. Roofing Costs.	When Tin Costs.	S. S. Roofing Costs.	S. S. Roofing Costs.	When Tin Costs.	S. S. Roofing Costs.	S. S. Roofing Costs.
Box.	Sq. Ft.	Sq.	Box.	Sq. Ft.	Sq.	Box.	Sq. Ft.	Sq.
$ 6.00	.0162	$1.62	$12.50	.0337	$3.37	$19.00	.0513	$5.13
6.50	.0175	1.75	13.00	.0351	3.51	19.50	.0526	5.26
7.00	.0189	1.89	13.50	.0364	3.64	20.00	.0540	5.40
7.50	.0202	2.02	14.00	.0378	3.78	20.50	.0553	5.53
8.00	.0216	2.16	14.50	.0391	3.91	21.00	.0567	5.67
8.50	.0230	2.30	15.00	.0404	4.04	21.50	.0580	5.80
9.00	.0243	2.43	15.50	.0418	4.18	22.00	.0594	5.94
9.50	.0256	2.56	16.00	.0432	4.32	22.50	.0607	6.07
10.00	.0270	2.70	16.50	.0446	4.46	23.00	.0621	6.21
10.50	.0283	2.83	17.00	.0459	4.59	23.50	.0634	6.34
11.00	.0297	2.97	17.50	.0473	4.73	24.00	.0648	6.48
11.50	.0310	3.10	18.00	.0486	4.86	.....	.....	..
12.00	.0324	3.24	18.50	.0500	5.00	..	..	..

The above estimates do not include cost of laying material

20 x 28 STANDING SEAM TIN ROOFING.

Table showing quantity of 20 x 28 tin required to cover a given number of square feet with Standing Seam Tin Roofing.

In the following estimates all fractional parts of a sheet are treated as a full sheet. Full size of sheet, 20 x 28, locked at ends. Covering surface, 474.9 square inches, or 3.3 square feet.

No. of Sq. Feet	Sheets required	No. of Sq. Feet	Sheets required	No. of Sq. Feet	Sheets required	No. of Sq. Feet	Sheets required	No. of Sq. Feet	Sheets required	No. of Sq. Feet	Sheets required	No. of Sq. Feet	Sheets required	No. of Sq. Feet	Sheets required
1	1	19	6	37	12	55	17	73	23	91	28	145	44	270	82
2	1	20	7	38	12	56	17	74	23	92	28	150	46	280	85
3	1	21	7	39	12	57	18	75	23	93	29	155	47	290	88
4	2	22	7	40	13	58	18	76	24	94	29	160	49	300	91
5	2	23	7	41	13	59	18	77	24	95	29	165	50	310	94
6	2	24	8	42	13	60	19	78	24	96	30	170	52	320	97
7	3	25	8	43	14	61	19	79	24	97	30	175	54	330	100
8	3	26	8	44	14	62	19	80	25	98	30	180	55	340	103
9	3	27	9	45	14	63	20	81	25	99	30	185	57	350	106
10	4	28	9	46	14	64	20	82	25	100	31	190	58	360	109
11	4	29	9	47	15	65	20	83	26	105	32	195	60	370	112
12	4	30	10	48	15	66	20	84	26	110	33	200	61	...	...
13	4	31	10	49	15	67	21	85	26	115	35	210	64	...	...
14	5	32	10	50	16	68	21	86	27	120	37	220	67	...	...
15	5	33	10	51	16	69	21	87	27	125	38	230	70	...	...
16	5	34	11	52	16	70	22	88	27	130	40	240	73	...	...
17	6	35	11	53	17	71	22	89	27	135	41	250	76	...	...
18	6	36	11	54	17	72	22	90	28	140	43	260	79	...	...

A full box, 20 x 28, 112 sheets, will cover approximately 370 square feet.

STOCK SIZES HEATER PIPE TIN.

SHEET	ROUND	OVAL
20"x23"	7"	4"x9"
20"x26"	8"	4"x10½
29"x29½"	9"	4"x12"
20"x32½"	10"	4"x14"
20"x38"	12"	4"x17"

SIZE OF SHEET NECESSARY TO MAKE 4 PC. ELBOWS

7"—12x23
8"—14x26
9"—14x29½
10"—15x32½
12"—16x38

NUMBER OF U. S. GALLONS IN RECTANGULAR TANKS

For One Foot in Depth

Width of Tank	LENGTH OF TANK																				
	2 ft.	2 ft. 6 in.	3 ft.	3 ft. 6 in.	4 ft.	4 ft. 6 in.	5 ft.	5 ft. 6 in.	6 ft.	6 ft. 6 in.	7 ft.	7 ft. 6 in.	8 ft.	8 ft. 6 in.	9 ft.	9 ft. 6 in.	10 ft.	10 ft. 6 in.	11 ft.	11 ft. 6 in.	12 ft.
2 ft.	30	37	45	52	60	67	75	82	90	97	105	112	120	127	135	142	150	157	166	172	180
2 ft. 6 in.	.....	47	56	65	75	84	94	103	112	122	131	140	150	159	168	178	187	196	206	215	224
3 ft.	.....	.....	67	79	90	101	112	123	135	146	157	168	180	191	203	213	224	236	247	258	269
3 ft. 6 in.	.....	.....	.....	92	105	118	131	144	157	170	183	196	209	223	236	249	262	275	288	301	314
4 ft.	.....	.....	.....	.....	120	135	150	165	180	194	209	224	239	254	269	284	299	314	329	344	359
4 ft. 6 in.	.....	.....	.....	.....	.....	151	168	185	202	219	236	252	269	286	303	320	337	353	370	387	404
5 ft.	.....	.....	.....	.....	.....	.....	187	206	224	243	262	281	299	318	337	355	374	393	411	430	449
5 ft. 6 in.	.....	.....	.....	.....	.....	.....	.....	226	247	267	288	309	329	350	370	391	411	432	453	473	494
6 ft.	.....	.....	.....	.....	.....	.....	.....	.....	269	292	314	337	359	381	404	426	449	471	494	516	539
6 ft. 6 in.	.....	.....	.....	.....	.....	.....	.....	.....	.....	316	340	365	389	413	438	462	486	511	535	559	583
7 ft.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	367	393	419	445	471	497	521	550	576	602	628
7 ft. 6 in.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	421	449	477	505	533	561	589	617	645	673
8 ft.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	479	509	540	569	598	628	658	688	718
8 ft. 6 in.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	540	572	604	636	668	699	731	763
9 ft.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	606	640	673	707	741	774	808
9 ft. 6 in.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	675	711	746	782	817	853
10 ft.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	748	785	823	860	898
10 ft. 6 in.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	825	864	903	943
11 ft.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	905	946	987
11 ft. 6 in.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	989	1032
12 ft.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1077

NUMBER OF GALLONS IN ROUND TANKS

Length or Depth in Feet	DIAMETER IN INCHES														
	18	24	30	36	42	48	54	60	66	72	78	84	90	96	108	120
	26	47	73	105	144	188	238	294	356	424	497	577	662	750	954	1178
2½	33	59	90	131	180	235	298	367	445	530	621	721	827	937	1192	1472
3	40	71	109	157	216	282	357	440	534	636	745	865	992	1124	1430	1766
3½	47	83	127	183	252	329	416	513	623	742	869	1009	1157	1311	1668	2060
4	54	95	145	209	288	376	475	586	712	848	993	1153	1322	1498	1904	2354
4½	61	107	163	235	324	423	534	659	801	954	1117	1297	1487	1685	2141	2648
5	68	119	180	261	360	470	593	732	890	1060	1241	1441	1652	1872	2382	2942
5½	75	131	200	287	396	517	652	805	979	1166	1365	1585	1817	2059	2620	3236
6	82	143	217	313	432	564	711	878	1068	1272	1489	1729	1982	2246	2858	3530
6½	89	155	235	339	468	611	770	951	1157	1378	1613	1873	2147	2433	3096	3824
7	96	167	253	365	504	658	829	1024	1246	1484	1737	2017	2312	2620	3334	4118
7½	103	179	271	391	540	705	888	1097	1335	1590	1861	2161	2477	2807	3572	4412
8	110	191	289	417	576	752	947	1170	1424	1696	1985	2305	2642	2994	3810	4706
8½	......	203	307	443	612	799	1006	1248	1513	1802	2109	2449	2807	3181	4048	5000
10	......	239	361	521	720	940	1183	1462	1780	2120	2481	2881	3302	3742	4762	5882
12	......	287	433	625	864	1128	1419	1754	2136	2544	2977	3457	3962	4490	5714	7058
14	......	......	......	......	1008	1316	1655	2046	2492	2968	3473	4033	4622	5238	6666	8234
16	......	......	......	......	1152	1504	1891	2338	2848	3392	3969	4609	5282	5986	7618	9410
18	......	......	......	......	......	......	2127	2630	3204	3816	4465	5185	5942	6734	8570	10586
20	......	......	......	......	......	......	2368	2922	3560	4240	4961	5761	6602	7482	9522	11762

TABLE OF DIAMETERS OF WIRE

IN DECIMAL PARTS OF AN INCH

As Represented by the Various Standard Gauges.

No. of Wire.	Washburn and Moen or A. S. & W. Co.	Old English or London.	American or Brown and Sharpe	Birmingham, Stub's, Peck, Stow & W., or British Standard.	U. S. Standard.*	Imperial Standard.
000000	.46				.46875	
00000	.43				.4375	
0000	.393	.454	.46	.454	.40625	.400
000	.362	.425	.410	.425	.375	.372
00	.331	.38	.365	.38	.34375	.348
0	.307	.34	.325	.34	.3125	.32
1	.283	.3	.289	.3	.28125	.300
2	.263	.284	.258	.284	.26562	.276
3	.244	.259	.229	.259	.25	.252
4	.225	.238	.204	.238	.23437	.232
5	.207	.22	.182	.22	.21875	.212
6	.192	.203	.162	.203	.20312	.102
7	.177	.18	.144	.18	.1875	.176
8	.162	.165	.128	.165	.17187	.160
9	.148	.148	.114	.148	.15625	.144
10	.135	.134	.102	.134	.14062	.128
11	.12	.12	.091	.12	.125	.116
12	.105	.109	.081	.109	.10937	.104
13	.092	.095	.072	.095	.09375	.092
14	.08	.083	.064	.083	.07812	.080
15	.072	.072	.057	.072	.07031	.072
16	.063	.065	.051	.065	.0625	.064
17	.054	.058	.045	.058	.05625	.056
18	.047	.049	.040	.049	.05	.048
19	.041	.04	.036	.042	.04375	.040
20	.035	.035	.032	.035	.0375	.036
21	.032	.0315	.028	.032	.03437	.032
22	.028	.0295	.025	.028	.03125	.028
23	.025	.027	.023	.025	.02812	.024
24	.023	.025	.020	.022	.025	.022
25	.02	.023	.018	.02	.02187	.020
26	.018	.0205	.016	.018	.01875	.018
27	.017	.01875	.014	.016	.01719	.0164
28	.016	.0165	.01264	.014	.01562	.0149
29	.015	.0155	.01126	.013	.01406	.0136
30	.014	.01375	.01002	.012	.0125	.0124
31	.0135	.01225	.00893	.01	.01094	.0116
32	.013	.01125	.00795	.009	.01016	.0108
33	.011	.01025	.00708	.008	.00937	.0100
34	.01	.0095	.00630	.007	.00859	.0092
35	.0095	.009	.00561	.005	.00781	.0081
36	.009	.0075	.005	.004	.00703	.0076
37	.0085	.0065	.00445		.00664	.0068
38	.008	.00575	.00396		.00625	.0060
39	.0075	.005	.00353		....	.0052
40	.007	.0045	.00314		....	.0048

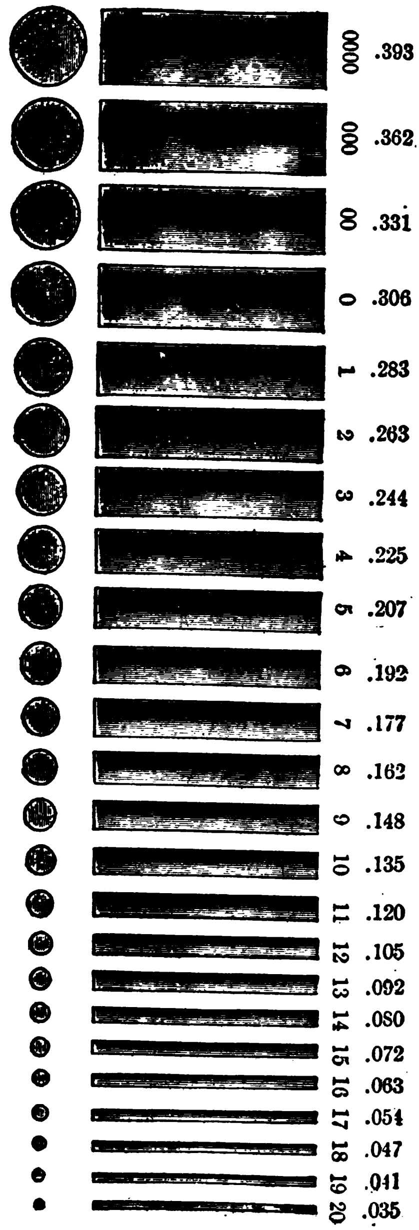

Fig. 189—Stubb's Wire Gauge.

WEIGHT, STRENGTH AND SIZE OF WIRE.

Gauge	Diam.	Approximate Size.	Length of 63 lbs.	Length of 100 lbs.	Length of 2000 lbs.	Length of one carload, 20,000 lbs.	Weight 100 feet	Weight one mile	Tensile Strength
	Ins.	Inches.	Feet.	Feet.	Feet.	Miles.	Lbs.	Lbs.	Lbs.
000	.362	3-8 in. scant	181	288	5,759	11	34.73	1,834	9,755
00	.331	11-32 " "	217	344	6,886	13	29.04	1,533	8,290
0	.307	5-16 " "	228	361	7,320	14	27.66	1,460	6,880
1	.283	9-32 "	296	471	9,425	18	21.23	1,121	5,650
2	.263		343	545	10,905	21	18.34	968	4,930
3	.244	1-4 " "	399	634	12,674	24	15.78	833	4,250
4	.225	7-32 " full	470	747	14,936	28	13.39	707	3,620
5	.207		555	881	17,621	33	11.35	599	3 040
6	.192	3-16 " "	647	1,028	20,555	39	9.73	514	2,510
7	.177		759	1,205	24,096	46	8.30	439	2,220
8	.162	5-32 " "	905	1,437	28,734	54	6.96	367	1,840
9	.148		1,086	1,724	34,483	65	5.80	306	1,560
10	.135		1,304	2,070	41,408	78	4.83	255	1,280
11	.120	1-8 in. scant	1,649	2,618	52,356	100	3.82	202	1,000
12	.105		2,168	3,425	68,493	130	2.92	154	800
13	.092	3-32 "	2,813	4,464	89,286	169	2.24	118	568
14	.080		3,728	5,917	118,343	224	1.69	89	456
15	.072		4,598	7,299	145,985	277	1.37	72	352
16	.063	1-16 "	6,000	9,524	190,476	360	1.05	55	264
17	.054		8,182	12,992	259,740	492	.77	41	208
18	.047		10,862	17,241	344,827	653	.58	31	160
19	.041		14,000	22,222	444,444	841	.45	24	128
20	.035	1-32 " full	19,687	31,250	625,000	1,185	.32	17	104

Melting Points of Different Metals

Antimony	951 degrees
Bismuth	470 degrees
Brass	1900 degrees
Bronze	1692 degrees
Copper	2548 degrees
Glass	2377 degrees
Gold (pure)	2590 degrees
Iron (cast)	3479 degrees
Iron (wrought)	3980 degrees
Lead	504 degrees
Platinum	3080 degrees
Silver (pure)	1250 degrees
Steel	2500 degrees
Tin	421 degrees
Zinc	740 degrees

Boiling Points of Various Fluids

Ether	100 degrees
Alcohol	173 degrees
Sul. Acid	240 degrees
Refined Petroleum	316 degrees
Turpentine	304 degrees
Sulphur	570 degrees
Linseed Oil	640 degrees
Water	212 degrees
Water in Vacuum	98 degrees

STANDARD SIZES OF REGISTERS.

Size of Opening.	Size of Opening.	Size of Opening.	Size of Opening.
4 x 6	6 x 30	12 x 14	18 x 27
4 x 8	6 x 32	12 x 15	18 x 30
4 x 10	7 x 7	12 x 16	18 x 36
4 x 12	7 x 10	12 x 17	20 x 20
4 x 13	7 x 12	12 x 18	20 x 22
4 x 15	7 x 14	12 x 19	20 x 24
4 x 18	8 x 8	12 x 20	20 x 26
4 x 21	8 x 10	12 x 24	20 x 28
4 x 24	8 x 12	12 x 30	20 x 30
5 x 8	8 x 14	12 x 36	20 x 36
5 x 9	8 x 16	14 x 14	21 x 29
5 x 10	8 x 18	14 x 16	22 x 22
5 x 12	8 x 20	14 x 18	22 x 24
5 x 14	8 x 21	14 x 20	22 x 26
5 x 16	8 x 24	14 x 22	22 x 28
5 x 18	8 x 30	14 x 24	22 x 30
6 x 6	9 x 9	16 x 16	24 x 24
6 x 8	9 x 12	16 x 18	24 x 27
6 x 9	9 x 13	16 x 20	24 x 30
6 x 10	9 x 14	16 x 22	24 x 32
6 x 12	9 x 16	16 x 24	24 x 36
6 x 14	9 x 18	16 x 28	27 x 27
6 x 16	10 x 10	16 x 30	27 x 38
6 x 18	10 x 12	16 x 32	30 x 30
6 x 20	10 x 14	16 x 36	30 x 36
6 x 22	10 x 16	18 x 18	30 x 42
6 x 24	10 x 18	18 x 21	30 x 48
6 x 28	10 x 20	18 x 24	*36 x 36
	12 x 12		*38 x 42

*Made to order.

DIMENSIONS OF REGISTERS

Size of opening, Inches	Nominal area of opening, Square Inches	Effective area of opening, Square Inches	Galv. Iron or Tin Box Size, Inches	Extreme dimensions of register face, Inches
6 x 10	60	40	6 9/16 x 10 9/16	7 11/16 x 11 11/16
8 x 10	80	53	8 5/8 x 10 5/8	9 3/4 x 11 3/4
8 x 12	96	64	8 5/8 x 12 5/8	9 3/4 x 13 3/4
8 x 15	120	80	8 5/8 x 15 5/8	9 3/4 x 16 11/16
9 x 12	108	72	9 11/16 x 12 11/16	10 7/8 x 13 7/8
9 x 14	126	84	9 11/16 x 14 11/16	10 7/8 x 15 7/8
10 x 12	120	80	10 11/16 x 12 11/16	11 15/16 x 13 15/16
10 x 14	140	93	10 11/16 x 14 11/16	11 15/16 x 15 15/16
10 x 16	160	107	10 11/16 x 16 11/16	11 15/16 x 17 7/8
12 x 15	180	120	12 3/4 x 15 3/4	14 1/16 x 17
12 x 19	228	152	12 3/4 x 19 3/4	14 1/16 x 21
14 x 22	308	205	14 7/8 x 22 7/8	16 1/4 x 24 1/4
15 x 25	375	250	15 7/8 x 25 7/8	17 1/4 x 27 1/4
16 x 20	320	213	16 7/8 x 20 7/8	18 5/16 x 22 5/16
16 x 24	384	256	16 7/8 x 24 7/8	18 5/16 x 26 5/16
20 x 20	400	267	20 15/16 x 20 15/16	22 3/8 x 22 3/8
20 x 24	480	320	20 15/16 x 24 15/16	22 3/8 x 26 3/8
20 x 26	520	347	20 15/16 x 26 15/16	22 3/8 x 28 3/8
21 x 29	609	403	21 15/16 x 29 15/16	23 3/8 x 31 3/8
27 x 27	729	486	27 15/16 x 27 15/16	29 3/8 x 29 3/8
27 x 38	1026	684	27 15/16 x 38 15/16	29 3/8 x 40 3/8
30 x 30	900	600	30 15/16 x 30 15/16	32 3/8 x 32 3/8

Dimensions of different makes of registers vary slightly. The above are for Tuttle & Bailey Mfg. Co.'s manufacture.

TABLE FOR SIZE OF CONDUCTORS.

Roof Area in sq. ft.	Discharge per sec. in cu. ft.	Dia. of Pipe, inches.	Area in in. required.
12,000	2.25	63.61	9
10,000	1.848	52.5	9
9,000	1.75	50.26	8
9,000	1.66	47.2	8
8,000	1.48	42	8
7,250	1.35	38.48	7
7,000	1.21	36.7	7
6,000	1.10	31.5	7
5,250	1.00	28.28	6
5,000	0.92	26.2	6
4,000	0.74	21	6
3,500	0.70	19.63	5
3,000	0.55	15.9	5
2,500	0.45	12.56	4
2,000	0.37	10.5	4
1,225	0.25	7.06	3
1,000	0.185	5.25	3
900	0.166	4.7	3
800	0.15	4.2	3
700	0.12	3.7	3
600	0.11	3.2	3
500	0.092	2.6	3
400	0.074	2.1	3
300	0.055	1.6	3
200	0.037	1.0	3
100	0.018	0.5	3

Square Feet of Surface in Round Grates of Different Diameters.

Inches.	Feet.	Inches.	Feet.
$13\frac{1}{2}$	1	$26\frac{5}{16}$	$3\frac{3}{4}$
15	$1\frac{1}{4}$	$27\frac{1}{8}$	4
$16\frac{1}{2}$	$1\frac{1}{2}$	28	$4\frac{1}{4}$
18	$1\frac{3}{4}$	$28\frac{3}{4}$	$4\frac{1}{2}$
$19\frac{3}{16}$	2	$29\frac{1}{2}$	$4\frac{3}{4}$
$20\frac{5}{16}$	$2\frac{1}{4}$	$30\frac{5}{16}$	5
$21\frac{1}{2}$	$2\frac{1}{2}$	$31\frac{3}{4}$	$5\frac{1}{2}$
$22\frac{1}{2}$	$2\frac{3}{4}$	$33\frac{3}{16}$	6
$23\frac{1}{2}$	3	$34\frac{1}{2}$	$6\frac{1}{2}$
$24\frac{1}{2}$	$3\frac{1}{4}$	$35\frac{13}{16}$	7
$25\frac{5}{16}$	$3\frac{1}{2}$		

WEIGHTS AND MEASURES

Troy Weight.

24 grains = 1 pwt.
20 pwts. = 1 ounce.
12 ounces = 1 pound.

Used for weighing gold, silver and jewels.

Apothecaries' Weight.

20 grains = 1 scruple.
3 scruples = 1 dram
8 drams = 1 ounce.
12 ounces = 1 pound.

The ounce and pound in this are the same as in Troy weight.

Avoirdupois Weight.

27 11-32 grains = 1 dram.
16 drams = 1 ounce.
16 ounces = 1 pound.
25 pounds = 1 quarter.
4 quarters = 1 cwt.
2,000 lbs. = 1 short ton.
2,240 lbs. = 1 long ton.

Dry Measure.

2 pints = 1 quart.
8 quarts = 1 peck.
4 pecks = 1 bushel.
36 bushels = 1 chaldron.

Liquid Measure.

4 gills = 1 pint.
2 pints = 1 quart.
4 quarts = 1 gallon.
31½ gallons = 1 barrel.
2 barrels = 1 hogshead.

Circular Measure.

60 seconds = 1 minute.
60 minutes = 1 degree.
30 degrees = 1 sign.
90 degrees = 1 quadrant.
4 quadrants = 12 signs, or
360 degrees = 1 circle.

Long Measure.

12 inches = 1 foot.
3 feet = 1 yard.
5½ yards = 1 rod.
40 rods = 1 furlong.
8 furlongs = 1 sta. mile.
3 miles = 1 league.

Square Measure.

144 sq. inches = 1 sq. ft.
9 sq. feet = 1 sq. yard.
30¼ sq. yds. = 1 sq. rod.
40 sq. rods = 1 rood.
4 roods = 1 acre.
640 acres = 1 sq. mile.

Time Measure.

60 seconds = 1 minute
60 minutes = 1 hour.
24 hours = 1 day.
7 days = 1 week.
28, 29, 30 or 31 days = 1 calendar month (30 days = 1 month in computing interest)
365 days = 1 year.
366 days = 1 leap year.

TABLE OF MILLIMETERS AND DECIMALS.

Millimeter	Decimal	Millimeter	Decimal
¾	.02952	6½	.25591
1	.03937	7	.27559
	.04687		.28125
1¼	.04921		.3125
1½	.05906	8	.31496
	.06250	9	.35433
	.07812		.375
2	.07874	10	.3937
2¼	.08858	11	.43307
	.09375		.4375
2½	.09843	12	.47244
3	.11811		.5
	.125	13	.51181
3¼	.12795	14	.55118
3½	.1378	15	.59055
	.14062		.59375
4	.15748		.625
4½	.17717	19	.74803
	.18750		.75
5	.19685	22	.86614
5½	.21654		.875
6	.23622	25	.98425
	.25		

Capacity in Gallons and Barrels of Round Tanks or Cisterns of Different Diameters 12″ Deep.

Diameter of Tank.	Gallons.	Barrels.
2 feet	23.4	
2½ "	36.72	1⅙
3 "	52.87	1⅝
3½ "	71.96	2¼
4 "	94.00	3
4½ "	118.97	3¾
5 "	146.88	4⅔
5½ "	177.72	5⅔
6 "	211.50	6¾
6½ "	248.22	7⅞
7 "	287.85	9⅕
7½ "	330.48	10½
8 "	376.00	12
8½ "	424.46	13½
9 "	475.87	15⅒
9½ "	528.75	16¾
10 "	587.04	18⅔
11 "	710.88	22½
12 "	846.00	26½

Horse Power of Belting

A simple rule for ascertaining transmitting power of belting without first computing speed per minute that it travels, is as follows:

Multiply diameter of pulley in inches by its number of revolutions per minute, and this product by width of the belt in inches; divide the product by 3,300 for single belting, or by 2,100 for double belting, and the quotient will be the amount of horse power that can be safely transmitted.

TABLE FOR SINGLE LEATHER, FOUR-PLY RUBBER AND FOUR-PLY COTTON BELTING, BELTS NOT OVERLOADED

1 Inch Wide, 800 Feet per Minute = 1 Horse Power.

Speed in feet per Minute	WIDTH OF BELTS IN INCHES											
	2	3	4	5	6	8	10	12	14	16	18	20
	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.	H. P.
400	1	1½	2	2½	3	4	5	6	7	8	9	10
600	1½	2¼	3	3¾	4½	6	7½	9	10½	12	13½	15
800	2	3	4	5	6	8	10	12	14	16	18	20
1000	2½	3¾	5	6¼	7½	10	12½	15	17½	20	22½	25
1200	3	4½	6	7½	9	12	15	18	21	24	27	30
1500	3¾	5¾	7½	9½	11½	15	18¾	22½	26½	30	33¾	37½
1800	4½	6¾	9	11¼	13½	18	22½	27	31½	36	40½	45
2000	5	7½	10	12¼	15	20	25	30	35	40	45	50
2400	6	9	12	15	18	24	30	36	42	48	54	60
2800	7	10½	14	17½	21	28	35	42	49	56	63	70
3000	7½	11¼	15	18¾	22½	30	37½	45	52½	60	67½	75
3500	8¾	13	17½	22	26	35	44	52½	61	70	79	88
4000	10	15	20	25	30	40	50	60	70	80	90	100
4500	11¼	17	22½	28	34	45	57	69	78	90	102	114
5000	12½	19	25	31	37½	50	62½	75	87½	100	112	125

Double leather, six-ply rubber or six-ply cotton belting will transmit 50 to 75 per cent. more power than is shown in this table. (One inch wide, 550 feet per minute = one horse power.)

TABLE OF COMMON FRACTIONS AND DECIMALS.

Fraction	Decimal	Fraction	Decimal
1/64	.015625	33/64	.515625
1/32	.03125	17/32	.53125
3/64	.046875	35/64	.546875
1/16	.0625	9/16	.5625
5/64	.078125	37/64	.578125
3/32	.09375	19/32	.59375
7/64	.109375	39/64	.609375
1/8	.125	5/8	.625
9/64	.140625	41/64	.640625
5/32	.15625	21/32	.65625
11/64	.171875	43/64	.671875
3/16	.1875	11/16	.6875
13/64	.203125	45/64	.703125
7/32	.21875	23/32	.71875
15/64	.234375	47/64	.734375
1/4	.25	3/4	.75
17/64	.265625	49/64	.765625
9/32	.28125	25/32	.78125
19/64	.296875	51/64	.796875
5/16	.3125	13/16	.8125
21/64	.328125	53/64	.828125
11/32	.34375	27/32	.84375
23/64	.359375	55/64	.859375
3/8	.375	7/8	.875
25/64	.390625	57/64	.890625
13/32	.40625	29/32	.90625
27/64	.421875	59/64	.921875
7/16	.4375	15/16	.9375
29/64	.453125	61/64	.953125
15/32	.46875	31/32	.96875
31/64	.484375	63/64	.984375
1/2	.5	1"	

TABLE OF AREAS AND CIRCUMFERENCES OF CIRCLES

Diam. Inches	Cir. Inches	Area Sq. In.	Diam. Inches	Cir. Inches	Area Sq. In.	Diam. Inches	Cir. Inches	Area Sq. In.
⅛	.393	.012	16	50.26	201.06	54	169.6	2290.2
¼	.785	.049	16½	51.83	213.82	55	172.7	2375.8
⅜	1.178	.110	17	53.40	226.98	56	175.9	2463.
½	1.570	.196	17½	54.97	240.52	57	179.	2551.7
⅝	1.963	.307	18	56.54	254.46	58	182.2	2642.
¾	2.356	.442	18½	58.11	268.80	59	185.3	2733 9
⅞	2.748	.601	19	59.69	283.52	60	188.4	2827.4
1	3.141	.785	19½	61.26	298.64	61	191.6	2922.4
1⅛	3.534	.994	20	62.83	314.16	62	194.7	3019.
1¼	3.927	1.227	20½	64.40	330.06	63	197.9	3117.2
1⅜	4.319	1.484	21	65.97	346.36	64	201.	3216.9
1½	4.712	1.767	21½	67.54	363.05	65	204.2	3318.3
1⅝	5.105	2.073	22	69.11	380.13	66	207.3	3421.2
1¾	5.497	2.405	22½	70.68	397.60	67	210.4	3525.6
1⅞	5.890	2.761	23	72.25	415.47	68	213.6	3631.6
2	6.283	3.141	23½	73.82	433.73	69	216.7	3739.2
2¼	7.068	3.976	24	75.39	452.39	70	219.9	3848.4
2½	7.854	4.908	24½	76.96	471.43	71	233.	3959.2
2¾	8.639	5.939	25	78.54	490.87	72	226.1	4071.5
3	9.424	7.068	26	81.68	530.93	73	229.3	4185.3
3¼	10.21	8.295	27	84.82	572.55	74	232.4	4300.8
3½	10.99	9.621	28	87.96	615.75	75	235.6	4417.8
3¾	11.78	11.044	29	91.10	660.52	76	238.7	4536.4
4	12.56	12.566	30	94.24	706.86	77	241.9	4656.6
4½	14.13	15.904	31	97.38	754.76	78	245.	4778.3
5	15.70	19.635	32	100.5	840.24	79	248.1	4901.6
5½	17.27	23.578	33	103.6	855.30	80	251.3	5026.5
6	18.84	28.274	34	106.8	907.92	81	254.4	5153.
6½	20.42	33.183	35	109.9	962.11	82	257.6	5281.
7	21.99	38.484	36	113.	1017.8	83	260.7	5410.6
7½	23.56	44.178	37	116.2	1075 2	84	263.8	5541.7
8	25.13	50.265	38	119.3	1134.1	85	267.	5674.5
8½	26.70	56.745	39	122.5	1194.5	86	270.1	5808.3
9	28.27	63.617	40	125.6	1256 6	87	273.3	5944.6
9½	29.84	70.882	41	128.8	1320.2	88	276.4	6082.1
10	31.41	78.539	42	131.9	1385.4	89	279.6	6221.1
10½	32.98	86.590	43	135.	1452.2	90	282.7	6361.7
11	34.55	95.033	44	138.2	1520.5	91	285.8	6503.8
11½	36.12	103.86	45	141.3	1590.4	92	289.	6647.6
12	37.69	113.09	46	144.5	1661.9	93	292.1	6792.9
12½	39.27	122.71	47	147.6	1734.9	94	295.3	6939.7
13	40.84	132.73	48	150.7	1809.5	95	298.4	7088.2
13½	42.41	143.13	49	153.9	1885.7	96	301.5	7238.2
14	43.98	153.93	50	157.	1963.5	97	304.7	7389.8
14½	45.55	165.13	51	160.2	2042.8	98	307.8	7542.9
15	47.12	176.71	52	163.3	2123.7	99	311.	7697.7
15½	48.69	188.69	53	166.5	2206.1	100	314.1	7853.9

Rules Relative to the Circle

To Find Circumference:
Multiply diameter by 3.1416.
Or divide diameter by 0.3183.

To Find Diameter:
Multiply circumference by 0.3183.
Or divide circumference by 3.1416.

To Find Radius:
Multiply circumference by 0.15915.
Or divide circumference by 6.28318.

To Find Size of an Inscribed Square:
Multiply diameter by 0.7071.
Or multiply circumference by 0.2251.
Or divide circumference by 4.4428.

To Find Side of an Equal Square:
Multiply diameter by 0.8862.
Or divide diameter by 1.1284.
Or multiply circumference by 0.2821.
Or divide circumference by 3.545.

Square:
A side multiplied by 1.4142 equals diameter of its circumscribing circle.
A side multiplied by 4.443 equals circumference of its circumscribing circle.
A side multiplied by 1.128 equals diameter of an equal circle.
A side multiplied by 3.545 equals circumference of an equal circle.
Square inches multiplied by 1.273 equals circle inches of an equal circle.

To Find the Area of a Circle:
Multiply circumference by one-quarter of the diameter.
Or multiply the square of diameter by 0.7854.
Or multiply the square of circumference by 0.07958.
Or multiply the square of one-half diameter by 3.1416.

To Find the Area of an Ellipse:
Multiply the product of its axes by .785398.
Or multiply the product of its semi-axes by 3.14159.

Contents of cylinder area = area of end × length.
Contents of wedge = area of base × one-half altitude.
Surface of cylinder = length × circumference + area of both ends.
Surface of sphere = diameter squared × 3.1416, or = diameter × circumference.
Contents of sphere = diameter cubed × 0.5236.
Contents of pyramid or cone, right or oblique, regular or irregular = area of base × one-third altitude.
Area of triangle = base × one-half altitude.
Area of parallelogram = base × altitude.
Area of trapezoid = altitude × one-half the sum of parallel sides.

CUBICAL CONTENTS OF ROOMS

HAVING CEILINGS OF THE FOLLOWING HEIGHTS

Floor Area			8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
3	x	3	72	77	81	85	90	95	99	108
3	x	3½	84	89	95	99	105	110	115	126
3	x	4	96	102	108	114	120	126	132	144
3	x	4½	108	115	122	128	135	142	148	162
3	x	5	120	128	135	142	150	158	165	180
3	x	5½	132	140	149	156	165	173	181	198
3	x	6	144	153	162	171	180	189	198	216
3½	x	3½	98	104	110	116	123	129	134	147
3½	x	4	112	119	126	133	140	147	154	168
3½	x	4½	126	134	142	149	158	165	173	189
3½	x	5	140	149	158	166	175	184	192	210
3½	x	5½	154	164	173	182	193	202	211	231
3½	x	6	168	179	189	199	210	221	231	252
3½	x	6½	182	193	205	216	228	239	250	273
3½	x	7	196	208	221	232	245	257	269	294
4	x	4	128	136	144	152	160	168	176	192
4	x	4½	144	153	162	171	180	189	198	216
4	x	5	160	170	180	190	200	210	220	240
4	x	5½	176	187	198	209	220	231	242	264
4	x	6	192	204	216	228	240	252	264	288
4	x	6½	208	221	234	247	260	273	286	312
4	x	7	224	238	252	266	280	294	308	336
4	x	7½	240	255	270	285	300	315	330	360
4	x	8	256	272	288	304	320	336	352	384
4½	x	4½	162	172	182	192	203	213	222	243
4½	x	5	180	191	203	213	225	236	247	270
4½	x	5½	198	210	223	235	248	260	272	297
4½	x	6	216	230	243	256	270	284	297	324
4½	x	6½	234	249	263	277	293	307	321	351
4½	x	7	252	268	284	299	315	331	346	378
4½	x	7½	270	287	304	320	338	354	371	405
4½	x	8	288	306	324	342	360	378	396	432
4½	x	8½	306	325	344	363	383	402	420	459
4½	x	9	324	345	365	384	405	425	445	486
5	x	5	200	212	225	237	250	263	275	300
5	x	5½	220	234	248	261	275	289	302	330
5	x	6	240	255	270	285	300	315	330	360
5	x	6½	260	276	293	308	325	341	357	390
5	x	7	280	297	315	332	350	368	385	420
5	x	7½	300	319	338	358	375	394	412	450
5	x	8	320	340	360	380	400	420	440	480
5	x	8½	340	361	383	403	425	446	467	510
5	x	9	360	382	405	427	450	473	495	540
5	x	9½	380	404	428	451	475	499	522	570
5	x	10	400	425	450	475	500	525	550	600
5½	x	5½	242	257	272	287	303	318	332	363
5½	x	6	264	281	297	313	330	347	363	396
5½	x	6½	286	304	322	339	358	375	393	429
5½	x	7	308	327	347	365	385	404	423	462
5½	x	7½	330	351	371	391	413	433	453	495
5½	x	8	352	374	396	418	440	462	484	528
5½	x	8½	374	397	421	444	468	491	514	561
5½	x	9	396	421	446	470	495	520	544	594
5½	x	9½	418	444	470	496	523	549	574	627

CUBICAL CONTENTS OF ROOMS

HAVING CEILINGS OF THE FOLLOWING HEIGHTS

Floor Area	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
5½ x 10	440	468	495	522	550	578	605	660
5½ x 10½	462	491	520	548	578	606	635	693
5½ x 11	484	514	545	574	605	635	665	726
6 x 6	288	306	324	342	360	378	396	432
6 x 6½	312	332	351	370	390	410	429	468
6 x 7	336	357	378	399	420	441	462	504
6 x 7½	360	383	405	427	450	473	495	540
6 x 8	384	408	432	456	480	504	528	576
6 x 8½	408	434	459	484	510	536	561	612
6 x 9	432	459	486	513	540	567	594	648
6 x 9½	456	485	513	541	570	599	627	684
6 x 10	480	510	540	570	600	630	660	720
6 x 10½	504	536	567	598	630	662	693	756
6 x 11	528	561	594	627	660	693	726	792
6 x 11½	552	587	621	655	690	725	759	828
6 x 12	576	612	648	684	720	756	792	864
6½ x 6½	338	359	380	401	423	444	464	507
6½ x 7	364	387	410	432	455	478	500	546
6½ x 7½	390	414	439	463	488	512	536	585
6½ x 8	416	442	468	494	520	546	572	624
6½ x 8½	442	470	497	524	553	580	607	663
6½ x 9	468	497	527	555	585	615	643	702
6½ x 9½	494	525	556	586	618	648	679	741
6½ x 10	520	553	585	617	650	683	715	780
6½ x 10½	546	580	614	648	683	717	750	819
6½ x 11	572	608	644	679	715	751	786	858
6½ x 11½	598	635	673	710	748	785	822	897
6½ x 12	624	663	702	741	780	819	858	936
6½ x 12½	650	691	731	771	813	853	898	975
6½ x 13	676	718	761	802	845	887	929	1014
7 x 7	392	417	441	465	490	515	539	588
7 x 7½	420	446	473	498	525	551	577	630
7 x 8	448	476	504	532	560	588	616	672
7 x 8½	476	506	536	565	595	625	654	714
7 x 9	504	536	567	598	630	662	693	756
7 x 9½	532	565	599	631	665	698	731	798
7 x 10	560	595	630	665	700	735	770	840
7 x 10½	588	625	662	698	735	772	808	882
7 x 11	616	655	693	731	770	809	847	924
7 x 11½	644	684	725	764	805	845	885	966
7 x 12	672	714	756	798	840	882	924	1008
7 x 12½	700	744	788	831	875	919	962	1050
7 x 13	728	774	819	864	910	956	1001	1092
7 x 13½	756	803	851	897	945	992	1039	1134
7 x 14	784	833	882	931	980	1029	1078	1176
7½ x 7½	450	478	506	534	563	591	618	675
7½ x 8	480	510	540	570	600	630	660	720
7½ x 8½	510	542	574	605	638	669	701	765
7½ x 9	540	574	608	641	675	709	742	810
7½ x 9½	570	606	641	676	713	748	783	855
7½ x 10	600	638	675	712	750	788	825	900
7½ x 10½	630	669	709	748	788	827	866	945
7½ x 11	660	701	743	783	825	866	907	990
7½ x 11½	690	733	776	819	863	906	948	1035

CUBICAL CONTENTS OF ROOMS

HAVING CEILINGS OF THE FOLLOWING HEIGHTS

Floor Area	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
7½ x 12	720	765	810	855	900	945	990	1080
7½ x 12½	750	797	844	890	938	984	1031	1125
7½ x 13	780	829	878	926	975	1024	1072	1170
7½ x 13½	810	861	911	961	1013	1063	1113	1215
7½ x 14	840	893	945	997	1050	1103	1155	1260
7½ x 14½	870	924	979	1033	1088	1142	1196	1305
7½ x 15	900	956	1013	1068	1125	1181	1237	1350
8 x 8	512	544	576	608	640	672	704	768
8 x 8½	544	578	612	646	680	714	748	816
8 x 9	576	612	648	684	720	756	792	864
8 x 9½	608	646	684	722	760	798	836	912
8 x 10	640	680	720	760	800	840	880	960
8 x 10½	672	714	756	798	840	882	924	1008
8 x 11	704	748	792	836	880	924	968	1056
8 x 11½	736	782	828	874	920	966	1012	1104
8 x 12	768	816	864	912	960	1008	1056	1152
8 x 12½	800	850	900	950	1000	1050	1100	1200
8 x 13	832	884	936	988	1040	1092	1144	1248
8 x 13½	864	918	972	1026	1080	1134	1188	1296
8 x 14	896	952	1008	1064	1120	1176	1232	1344
8 x 14½	928	986	1044	1102	1160	1218	1276	1392
8 x 15	960	1020	1080	1140	1200	1260	1320	1440
8 x 15½	992	1054	1116	1178	1240	1302	1364	1488
8 x 16	1024	1088	1152	1216	1280	1344	1408	1536
8½ x 8½	578	614	650	686	723	759	794	867
8½ x 9	612	650	689	726	765	803	841	918
8½ x 9½	646	686	727	767	808	848	888	969
8½ x 10	680	723	765	807	850	893	935	1020
8½ x 10½	714	759	803	847	893	937	981	1071
8½ x 11	748	795	842	888	935	982	1028	1122
8½ x 11½	782	831	880	928	978	1026	1075	1173
8¼ x 12	816	867	918	969	1020	1071	1122	1224
8½ x 12½	850	903	956	1009	1063	1116	1168	1275
8½ x 13	884	939	995	1049	1105	1160	1215	1326
8½ x 13½	918	975	1033	1090	1148	1205	1262	1377
8½ x 14	952	1012	1071	1130	1190	1250	1309	1428
8½ x 14½	986	1048	1109	1170	1233	1294	1355	1479
8½ x 15	1020	1084	1148	1211	1275	1339	1402	1530
8½ x 15½	1054	1120	1186	1251	1318	1383	1449	1581
8½ x 16	1088	1156	1224	1292	1360	1428	1496	1632
8½ x 16½	1122	1192	1262	1332	1403	1473	1542	1683
8½ x 17	1156	1228	1301	1372	1445	1517	1589	1734
9 x 9	648	689	729	769	810	851	891	972
9 x 9½	684	727	770	812	855	898	940	1026
9 x 10	720	765	810	855	900	945	990	1080
9 x 10½	756	803	851	897	945	992	1039	1134
9 x 11	792	842	891	940	990	1040	1089	1188
9 x 11½	828	880	932	982	1035	1087	1138	1242
9 x 12	864	918	972	1026	1080	1134	1188	1296
9 x 12½	900	956	1013	1068	1125	1181	1237	1350
9 x 13	936	995	1053	1111	1170	1229	1287	1404
9 x 13½	972	1033	1094	1154	1215	1276	1336	1458
9 x 14	1008	1071	1134	1197	1260	1323	1386	1512
9 x 14½	1044	1109	1175	1239	1305	1370	1435	1566

CUBICAL CONTENTS OF ROOMS

HAVING CEILINGS OF THE FOLLOWING HEIGHTS

Floor Area	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
9 x 15	1080	1148	1215	1282	1350	1418	1485	1620
9 x 15½	1116	1186	1256	1325	1395	1465	1534	1674
9 x 16	1152	1224	1296	1368	1440	1512	1584	1728
9 x 16½	1188	1262	1337	1410	1485	1559	1633	1782
9 x 17	1224	1301	1377	1453	1530	1607	1683	1836
9 x 17½	1260	1339	1418	1496	1575	1654	1732	1890
9 x 18	1296	1377	1458	1539	1620	1701	1782	1944
9½ x 9½	722	767	812	857	903	948	992	1083
9½ x 10	760	808	855	902	950	998	1045	1140
9½ x 10½	798	848	898	947	998	1047	1097	1197
9½ x 11	836	888	940	992	1045	1097	1149	1254
9½ x 11½	874	929	983	1038	1093	1147	1201	1311
9½ x 12	912	969	1026	1083	1140	1197	1254	1368
9½ x 12½	950	1009	1069	1128	1188	1247	1306	1425
9½ x 13	988	1050	1111	1173	1235	1297	1358	1482
9½ x 13½	1026	1090	1154	1218	1283	1347	1410	1539
9½ x 14	1064	1131	1197	1263	1330	1397	1463	1596
9½ x 14½	1102	1171	1240	1308	1378	1446	1515	1653
9½ x 15	1140	1211	1282	1353	1425	1496	1567	1710
9½ x 15½	1178	1252	1325	1398	1473	1546	1619	1767
9½ x 16	1216	1292	1368	1444	1520	1596	1672	1824
9½ x 16½	1254	1332	1411	1489	1568	1646	1724	1881
9½ x 17	1292	1373	1453	1534	1615	1696	1776	1938
9½ x 17½	1330	1413	1496	1579	1663	1746	1828	1995
9½ x 18	1368	1454	1539	1624	1710	1796	1881	2052
9½ x 18½	1406	1494	1582	1669	1758	1845	1933	2109
9½ x 19	1444	1534	1625	1714	1805	1895	1985	2166
10 x 10	800	850	900	950	1000	1050	1100	1200
10 x 10½	840	893	945	997	1050	1103	1155	1260
10 x 11	880	935	990	1045	1100	1155	1210	1320
10 x 11½	920	978	1035	1092	1150	1208	1265	1380
10 x 12	960	1020	1080	1140	1200	1260	1320	1440
10 x 12½	1000	1063	1125	1187	1250	1313	1375	1500
10 x 13	1040	1105	1170	1235	1300	1365	1430	1560
10 x 13½	1080	1148	1215	1282	1350	1418	1485	1620
10 x 14	1120	1190	1260	1330	1400	1470	1540	1680
10 x 14½	1160	1233	1305	1377	1450	1523	1595	1740
10 x 15	1200	1275	1350	1425	1500	1575	1650	1800
10 x 15½	1240	1318	1395	1472	1550	1628	1705	1860
10 x 16	1280	1360	1440	1520	1600	1680	1760	1920
10 x 16½	1320	1403	1485	1567	1650	1733	1815	1980
10 x 17	1360	1445	1530	1615	1700	1785	1870	2040
10 x 17½	1400	1488	1575	1662	1750	1838	1925	2100
10 x 18	1440	1530	1620	1710	1800	1890	1980	2160
10 x 18½	1480	1573	1665	1757	1850	1943	2035	2220
10 x 19	1520	1615	1710	1805	1900	1995	2090	2280
10 x 19½	1560	1658	1755	1852	1950	2048	2145	2340
10 x 20	1600	1700	1800	1900	2000	2100	2200	2400
11 x 11	968	1029	1089	1149	1210	1271	1331	1452
11 x 12	1056	1122	1188	1254	1320	1386	1452	1584
11 x 13	1144	1216	1287	1358	1430	1502	1573	1716
11 x 14	1232	1309	1386	1463	1540	1617	1694	1848
11 x 15	1320	1403	1485	1567	1650	1733	1815	1980
11 x 16	1408	1496	1584	1672	1760	1848	1936	2112

CUBICAL CONTENTS OF ROOMS

HAVING CEILINGS OF THE FOLLOWING HEIGHTS

Floor Area	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
11 x 17	1496	1590	1683	1776	1870	1964	2057	2244
11 x 18	1584	1683	1782	1881	1980	2079	2178	2376
11 x 19	1672	1777	1881	1986	2090	2195	2299	2508
11 x 20	1760	1870	1980	2090	2200	2310	2420	2640
11 x 21	1848	1964	2079	2194	2310	2426	2541	2772
11 x 22	1936	2057	2178	2299	2420	2541	2662	2904
12 x 12	1152	1224	1296	1368	1440	1512	1584	1728
12 x 13	1248	1326	1404	1482	1560	1638	1716	1872
12 x 14	1344	1428	1512	1596	1680	1764	1848	2016
12 x 15	1440	1530	1620	1710	1800	1890	1980	2160
12 x 16	1536	1632	1728	1824	1920	2016	2112	2304
12 x 17	1632	1734	1836	1938	2040	2142	2244	2448
12 x 18	1728	1836	1944	2052	2160	2268	2376	2592
12 x 19	1824	1938	2052	2166	2280	2394	2508	2736
12 x 20	1920	2040	2160	2280	2400	2520	2640	2880
12 x 21	2016	2142	2268	2394	2520	2646	2772	3024
12 x 22	2112	2244	2376	2508	2640	2772	2904	3168
12 x 23	2208	2346	2484	2622	2760	2898	3036	3312
12 x 24	2304	2448	2592	2736	2880	3024	3168	3456
13 x 13	1352	1437	1521	1605	1690	1775	1859	2028
13 x 14	1456	1547	1638	1729	1820	1911	2002	2184
13 x 15	1560	1658	1755	1852	1950	2048	2145	2340
13 x 16	1664	1768	1872	1976	2080	2184	2288	2496
13 x 17	1768	1879	1989	2099	2210	2321	2431	2652
13 x 18	1872	1989	2106	2223	2340	2457	2574	2808
13 x 19	1976	2100	2223	2346	2470	2594	2717	2964
13 x 20	2080	2210	2340	2470	2600	2730	2860	3120
13 x 21	2184	2321	2457	2593	2730	2867	3003	3276
13 x 22	2288	2431	2574	2717	2860	3003	3146	3432
13 x 23	2392	2542	2961	2840	2990	3140	3289	3588
13 x 24	2496	2652	2808	2964	3120	3276	3432	3744
13 x 25	2600	2763	2925	3087	3250	3413	3575	3900
13 x 26	2704	2873	3042	3211	3380	3549	3718	4056
14 x 14	1568	1666	1764	1862	1960	2058	2156	2352
14 x 15	1680	1785	1890	1995	2100	2205	2310	2520
14 x 16	1792	1904	2016	2128	2240	2352	2464	2688
14 x 17	1904	2023	2142	2261	2380	2499	2618	2856
14 x 18	2016	2142	2268	2394	2520	2646	2772	3024
14 x 19	2128	2261	2394	2527	2660	2793	2926	3192
14 x 20	2240	2380	2520	2660	2800	2940	3080	3360
14 x 21	2352	2499	2646	2793	2940	3087	3234	3528
14 x 22	2464	2618	2772	2926	3080	3234	3388	3696
14 x 23	2576	2737	2898	3059	3220	3381	3542	3864
14 x 24	2688	2856	3024	3192	3360	3528	3696	4032
14 x 25	2800	2975	3150	3325	3500	3675	3850	4200
14 x 26	2912	3094	3276	3458	3640	3822	4004	4368
14 x 27	3024	3213	3402	3591	3780	3969	4158	4536
14 x 28	3136	3332	3528	3724	3920	4116	4312	4704
15 x 15	1800	1913	2025	2137	2250	2363	2475	2700
15 x 16	1920	2040	2160	2280	2400	2520	2640	2880
15 x 17	2040	2168	2295	2422	2550	2678	2805	3060
15 x 18	2160	2295	2430	2565	2700	2835	2970	3240
15 x 19	2280	2423	2565	2707	2850	2993	3135	3420
15 x 20	2400	2550	2700	2850	3000	3150	3300	3600

CUBICAL CONTENTS OF ROOMS

HAVING CEILINGS OF THE FOLLOWING HEIGHTS

Floor Area	8 ft.	8½ ft.	9 ft.	9½ ft.	10 ft.	10½ ft.	11 ft.	12 ft.
15 x 21	2520	2678	2835	2992	3150	3308	3465	3780
15 x 22	2640	2805	2970	3135	3300	3465	3630	3960
15 x 23	2760	2933	3105	3277	3450	3623	3795	4140
15 x 24	2880	3060	3240	3420	3600	3780	3960	4320
15 x 25	3000	3188	3375	3562	3750	3938	4125	4500
15 x 26	3120	3815	3510	3705	3900	4095	4290	4680
15 x 27	3240	3443	3645	3847	4050	4253	4455	4860
15 x 28	3360	3570	3780	3990	4200	4410	4620	5040
15 x 29	3480	3698	3915	4132	4350	4568	4785	5220
15 x 30	3600	3825	4050	4275	4500	4725	4950	5400
16 x 16	2048	2176	2304	2432	2560	2688	2816	3072
16 x 17	2176	2312	2448	2584	2720	2856	2992	3264
16 x 18	2304	2448	2592	2736	2880	3024	3168	3456
16 x 19	2432	2584	2736	2888	3040	3192	3344	3648
16 x 20	2560	2720	2880	3040	3200	3360	3520	3840
16 x 21	2688	2856	3024	3192	3360	3528	3696	4032
16 x 22	2816	2992	3168	3344	3520	3696	3872	4224
16 x 23	2944	3128	3312	3496	3680	3864	4048	4416
16 x 24	3072	3264	3456	3648	3840	4032	4224	4608
16 x 25	3200	3400	3600	3800	4000	4200	4400	4800
16 x 26	3328	3536	3744	3952	4160	4368	4576	4992
16 x 27	3456	3672	3888	4104	4320	4536	4752	5184
16 x 28	3584	3808	4032	4256	4480	4704	4928	5376
16 x 29	3712	3944	4176	4408	4640	4872	5104	5568
16 x 30	3840	4080	4320	4560	4800	5040	5280	5760
16 x 31	3968	4216	4464	4712	4960	5208	5456	5952
16 x 32	4096	4352	4806	4864	5120	5376	5632	6144
18 x 18	2592	2754	2916	3078	3240	3402	3564	3888
18 x 20	2880	3060	3240	3420	3600	3780	3960	4320
18 x 22	3169	3366	3564	3762	3960	4158	4356	4752
18 x 24	3456	3672	3888	4104	4320	4536	4752	5184
18 x 26	3744	3978	4212	4446	4680	4914	5148	5616
18 x 28	4032	4284	4536	4788	5040	5292	5544	6048
18 x 30	4320	4590	4860	5130	5400	5670	5940	6480
18 x 32	4608	4896	5184	5472	5760	6048	6336	6912
18 x 34	4896	5202	5508	5814	6120	6426	6732	7344
18 x 36	5184	5508	5832	6156	6480	6804	7128	7776
20 x 20	3200	3400	3600	3800	4000	4200	4400	4800
20 x 22	3520	3740	3960	4180	4400	4620	4840	5280
20 x 24	3840	4080	4320	4560	4800	5040	5280	5760
20 x 26	4160	4420	4680	4940	5200	5460	5720	6240
20 x 28	4480	4760	5040	5320	5600	5880	6160	6720
20 x 30	4800	5100	5400	5700	6000	6300	6600	7200
20 x 32	5120	5440	5760	6080	6400	6720	7040	7680
20 x 34	5440	5780	6120	6460	6800	7140	7480	8160
20 x 36	5760	6120	6480	6840	7210	7560	7920	8640
20 x 38	6080	6460	6840	7220	7600	7980	8360	9120
20 x 40	6400	6800	7200	7600	8000	8400	8800	9600

CHAPTER XX

RECIPES AND MISCELLANEOUS DATA

To Clean Brass.

Mix in a stone jar one part of nitric acid, and one-half part of sulphuric acid. Dip the brasswork into this mixture, wash it off with water, and dry with sawdust. If greasy, dip the work into a strong mixture of potash, soda and water, to remove the grease, and wash it off with water.

To Clean Zinc.

Dissolve a teaspoonful of oxalic acid in a half pint of water, and wash the zinc with the solution, after which the zinc should be washed off with water, and polished witha woolen cloth and dry whiting.

To Clean Out Water Front That is Filled With Rust.

Take the water front out and place it in a forge or in a furnace, and heat it. This will bake the deposit that has collected in the water front, and will loosen much of it.

After being sufficiently heated, it should be removed, and tapped with a hammer to dislodge the rust that clings to the surface. In this way the water front may be entirely cleaned.

To Remove Lime Deposit in a Water Front.

After disconnecting the range, take out the water front, and immerse it in muriatic acid, where it should remain two or three hours, according to the amount of deposit and the strength of the acid. On removing the water front from the acid, plunge it into water and wash thoroughly.

Government Recipe for Cleaning Brass.

The following is said to be the method used in government arsenals for cleaning brass. Use two parts of common nitric acid to one part of sulphuric acid. The acid should be kept in a stone jar. Articles that are to be cleaned should be first dipped into the acid, then into clear water, and then dried with sawdust. This cleaning process will change the brass at once to a brilliant color. If the metal to be cleaned is

greasy, the grease should be first removed, by dipping the article in a strong solution of potash and soda in warm water.

To Prevent Rusting of Iron and Steel.

Cover the surface with a mixture made of 1 lb. melted lard, 1 oz. camphor, and black lead to give it the desired color. By covering the surface with this mixture, the metal will be protected for an indefinite length of time, and it may be cleaned off with naptha or benzine.

To Prevent Polished Iron From Rusting.

Cut a small amount of beeswax with benzine, and supply it to the surface of the polished iron. This has long been in use in protecting Russia iron through the damp season, and has been found very effective.

To Clean Zinc.

Zinc is generally cleaned by scouring it with fine sand and pumice. A bath of two parts of nitric acid, and one part sulphuric acid will also give results. The bath should be followed by a water bath.

After cleaning zinc, a permanent bright surface may be obtained by giving it a coat of transparent varnish.

How to Clean Steel Tapes.

Cover the tape with crude oil and rub down with No. O steel wool. This will clean the rust from the tape without injury to the etching. If the tape is not very rusty it may be brightened up by rubbing with powdered pumice or dry cement.

To Paint Galvanized Iron.

There is very often difficulty in making paint stick to galvanized iron. The galvanized iron should first be cleaned with a solution of ammonia and water. When the iron has dried off, it is ready for the paint, which will then adhere without any difficulty.

To Keep Plaster of Paris From Setting Too Quickly.

Sift the plaster into the water, allowing it to soak up the water, without stirring, which would admit air and cause the plaster to set quickly. If desired to keep the plaster soft for a much longer time, add to every quart of water, one-half teaspoonful of common cooking soda. This will gain all the time necessary.

To Solder Galvanized Iron.

Be sure to have a very hot soldering copper in soldering galvanized iron, even though it has to be returned often. When the copper is not sufficiently hot, it simply solders to the surface of the zinc, which is liable to peel off. In having the iron hot, the soldering gets to the iron, and the solder and zinc are more thoroughly fused together and to the iron.

A Flux for Tin Roofing.

A good roofing flux is made of two parts of binnacle oil, and one part of rosin. Rosin, cut with alcohol, and applied with a swab, also is very satisfactory.

Fluxes for Various Metals.

For cast and malleable iron and steel, borax and sal-ammoniac. For brass, gun metal and copper, chloride of zinc, sal-ammoniac or rosin. For zinc, chloride of zinc. For tinned iron, chloride of zinc or rosin. For lead, tallow for coarse solder, and rosin for fine solder. For pewter, gallipoli oil.

To Keep Soldering Coppers in Order While Soldering With Acid.

In a pint of water dissolve a piece of sal-ammoniac about the size of a walnut. Whenever the copper is taken from the fire, dip the point into the liquid, and the zinc taken from the acid will run to the point of the copper and can then be shaken off, leaving the copper bright.

A Good Soldering Acid.

In 1 lb. muriatic acid, dissolve all the zinc it will take up, thereby forming zinc chloride. Add to the zinc chloride 1 ounce of sal-ammoniac. Reduce with the same amount of water there is of the acid.

A Non-Corrosive Soldering Paste.

An excellent paste for soldering purposes can be made of one part by weight, of chloride of zinc, and sixteen parts of some such grease as vaseline, thoroughly mixed together. The chloride of zinc is known to every tinsmith, and is made by dissolving in muriatic acid, as much zinc as the acid will eat up.

Waterproof Glue.

Use one part India rubber, and three parts gum shellac, by weight.

Dissolve each in separate vessels, in ether, and under a mild heat.

After being completely dissolved, mix the two, and keep in an air-tight vessel. This mixture will withstand both hot and cold water, and nearly all kinds of acids.

Common glue, mixed with varnish or linseed oil, applied to the parts to be glued after they have been warmed, will be permanent and with stand water.

How to Make Putty.

Mix dry whiting with raw linseed oil. For glazing, add about 10 per cent. of white lead to increase durability. In hot climates a little cottonseed oil should be added to prevent the putty from drying too quickly.

Fireproof Cement for Furnaces.

A cement or mortar that will close up cracks in furnaces to keep the gas from escaping can be made as follows: Mix together seventy-five parts of wet fire clay, three parts of black oride manganese, three parts of white sand and one part of powdered asbestos. Thoroughly mix by adding enough water to make a smooth paste. Apply over the cracks and when dry it will be as hard as iron and stick like glue.

Rust Joints.

To make a good rust joint, use 5 lbs. iron filings, and 1 oz. each of sal-ammoniac and flour of sulphur. Do not use a greater amount of sal-ammoniac as it is likely to generate heat, and thereby cause expansion. A stronger but slower setting cement may be made by using the following proportions of ingredients: 12 lbs. iron filings, 2 ozs. sal-ammoniac, and 1 oz. flour of sulphur.

Friction of Water in Passing Through Pipes.

Friction of Water in pipes is approximately equal to the square of the velocity at which it is flowing.

Therefore the greater the velocity, the greater the friction will be. The friction of water in passing a 90 degree bend is as great as the friction of a length of such pipe 38 times as great as the diameter. The friction of water in small pipes is much greater than in large pipes, as in the small pipe a much larger proportion of the water comes in contact with the sides of the pipe.

Heating Capacity of Stove and Furnace Coils.

When a stove or furnace heating coil is so placed as to be covered by the fire, it is estimated that it will take about one square foot of heating surface in the coil to heat fifteen gallons of water in the boiler.

If the coil is to be of ¾ inch pipe, it will require 45 inches of pipe for each 15 gallons of tank capacity. If a 1 inch coil is to be used, it will require 3 feet of pipe for 15 gallons.

In the case of furnace coils that are placed in the combustion chamber, above the fire, the heating power of the coil will not be so great, for the reason that when the feed door is opened, or fresh coal is thrown onto the fire, the heating of the coil is checked. Under these circumstances it would not generally be safe to figure on heating much over 10 gallons per square foot of heating surface.

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Furnace Heating

INDEX II

Furnace Fittings